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POTENTIAL DISTRIBUTION OF THE RATED OFFICER FORCE AND THEIR IMP--ETC(U)
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UNITED STATES AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

GOR/SM/76D-1

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POTENTIAL DISTRIBUTIONS OF THE RATED
OFFICER FORCE AND THEIR IMPLICATIONS IN
FUTURE CONFLICT

Thesis

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GOR/SM/76D-1

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POTENTIAL DISTRIBUTIONS OF THE RATED OFFICER FORCE AND THEIR IMPLICATIONS IN FUTURE CONFLICT

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by
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December 1976

PREFACE

In this thesis, I have attempted to address the important, often overlooked, stochastic element of the rated officer force structure, indeed of the whole Air Force manpower system. In my work, I have endeavored to quantify this stochastic element at work within the manpower system and complicating the task of manpower planners in the Air Force. It is my hope that the models developed herein and the inferences drawn from them will be of use to these planners as they attempt to man the Air Force of the future.

To my knowledge, the approach to this problem as well as the data base developed for it are unique. To accomplish this task, many individuals were consulted to whom I am indebted for their help. The list is too long to cite here. The cooperation I received from Air Force officers and civilians alike, far exceeded my expectations. This speaks very well for the Air Force community and is gratifying to me.

Special attention is due to my advisor, Major Saul Young, who guided me through the entire task and to my reader, Major Chuck McNichols, who kept me statistically honest.

Last but certainly not least, I am indebted to my wife who spent many long hours typing draft copies and, more than that, tolerated my various moods, high and low. For her support I am truly greatful; without it I would have certainly failed.

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ABSTRACT

Changes in the composition of the USAF rated officer force are viewed as a stochastic process influenced by the decisions of individual service members and manpower planners.

Both pilots and navigators are considered separately. Data are developed based on the product of crews formed by weapon system and pilots or navigators per crew for the same weapon system. Rated officers are then aggregated into broad categories for further analysis. Multiple linear regression conforming to the Standard Linear Model is used to develop the explicit forms of relationships between the numbers of pilots or navigators in the categories and relevant independent variables. The basic hypothesis tested is that pilots or navigators in a particular category are a function of aircraft in that same category. Using this hypothesis as an underlying guide, some 20 models are developed which are then used to forecast future distributions of the rated officer force. The implications of the analysis are discussed in light of potential wartime needs for rated officers.

The study concludes that the Standard Linear Model is apt for the problem addressed and large variance is a characteristic of the manpower system under examination and that forecasting with reasonable accuracy in this way is virtually impossible. Other significant observations include a tendency to overman the pilot force and an apparent delay in planning for navigators relative to pilots.

I. INTRODUCTION

The concept of deterrence on which the current foreign policy of the United States rests depends on an ability to rapidly deploy and employ combat forces should deterrence fail. In order to support this objective, the United States Air Force (USAF) maintains a fighting force of both equipment and the manpower to operate it. The effectiveness with which the USAF responds to wartime demands depends critically on the number of trained people available when they are needed as well as their degree of readiness. This base of manpower must be able to support employment of USAF forces across a spectrum of possible conflict situations from limited war to strategic nuclear war. Thus the manpower system must be flexible enough to shift in response to changes in manpower needs dictated by different conflict situations.

Perhaps the most important element of the total manpower system of the USAF in a wartime context is the rated officer force. The ability of the USAF to respond to conflict certainly depends on both the quantity and quality of the rated force. In addition, an important consideration in planning for future rated forces is what we will term the state of the manpower system when conflict occurs. This concept includes such factors as the number of rated officers, how many are actively flying, which aircraft each officer is qualified to fly in combat, and other related information. When conflict occurs, the state of the system will definitely effect the eventual outcome of the conflict.

One of the more important factors to consider in planning for future rated forces is the qualification status of rated officers. That is, what aircraft is each officer qualified to fly. An abundance of pilots

and navigators qualified in airlift aircraft does little (short-term) good if what is needed is fighter pilots. Such a situation would necessitate a retraining program to qualify pilots of airlift aircraft to fly fighter aircraft. This process would consume valuable time -- a cricical factor in wartime.

At any point in time, knowledge of the state of the system would include information about the qualification status of each rated officer. This, in turn, would permit categorizing the entire rated force according to weapon system. If the categories were mutually exclusive and collectively exhaustive (i.e. every officer counter only once), then one would have a distribution of the rated force, by weapon system, indicating the qualification status of the entire rated force. Given the manpower needs dictated by a potential conflict, one could then determine a desired distribution of the rated force and compare this with a forecasted actual distribution. Inferences could then be drawn about the consequences of the (inevitable) differences in distributions.

This thesis presents an approach to forecasting these future distributions of the rated officer force. The categories, which will be specified shortly, are highly aggregated but meet the requirements of being mutually exclusive and collectively exhaustive. Actual forecasts are developed and their implications are discussed in light of potential conflict situations.

Background

To plan for and create a suitable rated force poses many difficulties for manpower planners. Because of the many possible conflict situations to which this force must respond, it is questionable what a suitable distribution of the rated force should be. Nor is this the

only dimension of the total manpower-planning problem. An almost overpowering number of constraints are placed on manpower planners when they attempt to plan for the future. They must insure that the number of officers in each grade (rank) is within prespecified limits so as not to create "humps" in any one grade. They must insure that each individual officer has an orderly progression through the various stages of his career. They must plan for some movement of personnel among duty assignments, but not too much. They must do all these things within the manpower ceilings established by the Congress and at minimum cost! The dimensions of the manpower planner's problem are indeed many.

Recent advances in the management sciences (e.g. systems analysis, operations research, etc.) have produced several useful manpower planning models. These models are attempts to represent some portion of the manpower system with a series of mathematical expressions. The models usually make generous use of the computer. Because of the multidimensional nature of the manpower system of the USAF, those models developed for or in use by the USAF take differing variables into account and view the manpower system from differing perspectives. That is, they address but one dimension of the system. Examples of these models abound but only two will be described here.

<u>TOPLINE Model</u>. This is a static planning model which can reasonably be classified as a simulation model. The name TOPLINE derives from the USAF program of the same name. The model simulates the dynamic operation of the USAF officer-personnel system and is used to test the effects of policy changes on the long-run (i.e. 10-15 years hence) structure of the line officer force (Miller 1973). In this model, the emphasis is on the detailed movements and promotions of each officer. Thus the primary dimension addressed by this model is that of rank structure.

Career Area Rotation Model (CAROM). Although this model is used to examine the enlisted force structure of the USAF, it serves to illustrate emphasis on a different dimension of the total USAF manpower system. The model employs a linear programming approach to the problem of allocating manpower to authorized positions (sometimes referred to as allocating "faces to spaces"). Application of this model was proposed in 1972 by Hatch, and quickly adopted by the USAF (Williams 1973). Clearly, the emphasis of this model is on the detailed job structure of the enlisted force. That is, both people and spaces are taken as given and the "problem" is to allocate the former to the latter in some optimal way.

The important element overlooked by these two models (as well as others) is the random element at work in the manpower system. Although the structure of the USAF manpower structure can be manipulated through policy changes, these changes may or may not influence the decisions of individuals regarding their respective careers. Several decisions (e.g. voluntary attendance at professional military school, declining promotion, separation, etc.) are left to the individual service member. These decisions, taken collectively, change the system from a deterministic one to a stochastic one and can have a profound influence on the structure of the USAF manpower system and the rated force in particular. It is this stochastic influence and its importance which demands attention in this thesis. In addition, considering the abundance of models which address the details of the USAF manpower system, an aggregate view of the system seems appropriate.

Statement of Problem

The approach described herein addresses a primary and a secondary question:

(1) Can changes in the distribution of the rated officer force be represented by a statistical, linear (stochastic) model suitable for forecasting future distributions?

(2) Given the distributions thus forecast, what are the implications of these in light of wartime manpower needs for selected wartime scenarios?

Stated a different way, one could say that the individual commands, when expressing their requirements for rated manpower, consider the number of aircraft they must man. These requirements collectively motivate manpower planners to change (or not change) the distribution of the rated force. The distribution that results then influences the ability of the USAF to respond to different conflicts. We are thus interested in forecasting what manpower planners will do to meet differing requirements in the future.

Approach

The rated force is divided into 20 broad categories depending (primarily) on what type aircraft is flown. The categories are rated officers flying Bombers, Tankers, Fighter/Attack aircraft, Reconnaissance aircraft, Airlift aircraft, Other aircraft; those attending Air Force Institute of Technology (AFIT) programs and Professional Military Education (PME) Schools; Undergraduate Pilot Trainees (UPT's) and Undergraduate Navigator Trainers (UNT's); and those in the Supplement. These categories are duplicated for both pilots and navigators, respectively.

Past numbers of both pilots and navigators in each category are sampled annually. The numbers of aircraft in these same categories (where applicable) are then sampled at the same times. Finally, data are

sampled for other variables which are judged as related. Development of the data is addressed in Chapter II.

Using the data above, multiple regression analysis is used to develop the explicit forms of the relationships among the variables and to choose those judged most significant (Chapter III). Then the results of this analysis are used to forecast distributions of pilots and navigators into the future (Chapter IV). These forecasts form the basis for analysis of the secondary study objective (Chapter V).

In determining the implications of these future distributions, the potential effects of differences between the distributions themselves and distributions that might be needed in future conflict situations are noted and discussed. For example, a full-scale, nonnuclear war might be expected to increase the number of rated personnel needed in the fighter category. The process by which these needs are filled (from supplement or UPT/UNT categories, for example) is also discussed. The variable of interest in this process is the time required to reach the desired distribution. The influence of war type of needs in each of the categories is examined in light of current war plans.

<u>Scope</u>. This study is limited by the following:

1. Only the active rated force is examined. No Air National Guard or Air Force Reserve forces are considered. This restriction also applies to aircraft.
2. Forecasts of pilot and navigator distributions are limited to a maximum of five years. This restriction derives from the forecasts of aircraft inventories found in the Five ear Defense Plan (FYDP).
3. Historical data cover the period of Fiscal Year 1959 to Fiscal Year 1975.

Hypotheses. To establish the relationships needed for forecasting, the following major hypotheses are tested:

1. The numbers of the rated officers that fall into the various categories are functions of the respective numbers of aircraft in the inventory that fall into the same categories. The functional forms judged best are determined by testing several relationships.
2. The number of rated officers in the supplement is a function of the ratio of total pilots to total aircraft.
3. The number of UPT's and UNT's is a function of the fraction of the rated force actively flying aircraft.

In addition to these three major hypotheses, several others are tested depending on whether those relationships tested before them reached statistical significance.

Assumptions. The major assumptions of this study are:

1. The number of aircraft in a given category is an adequate measure of the relative need (in peacetime) for rated officers in that category.
2. Random error is introduced by manpower planners attempting to meet requirements expressed by the Commands as well as by rated officers' decisions which render the system stochastic.
3. Error introduced in some time period is statistically independent of error introduced in any other time period.
4. Current training policies for rated officers will remain in effect for at least five years.

II. DATA DEVELOPMENT

This chapter presents the data developed for use in the various regression analyses together with a description of the way in which they were developed. Alternative sources for the data are discussed and the rationale for rejecting them is presented.

Considering the length of time that manpower planners have been providing for the training, education, and finally flying duty of rated officers, it is surprising to note the paucity of data now in existence. Nevertheless, some means had to be found to develop the needed data which extended sufficiently into the past to insure enough data points for meaningful regression analysis. This small data base problem was further aggravated by the stochastic dependence between successive observations. That is, since Air Force tours are typically longer than one year duration, a rated officer in one category could be in the same category in the subsequent sample. Thus, sampling the rated force at one year intervals could lead to error terms in the regression equations which were not stochastically independent -- a violation of the conditions of the standard linear model being used. If the sample interval were decreased in an attempt to increase sample size, the dependence problem would have become worse. On the other hand, increasing the sample interval would have decreased the sample size which was already small. To strike a balance between these two extremes, a sample interval of one year was selected as a reasonable compromise.

A logical first choice for the necessary data was the Master Personnel File maintained by the Air Force Military Personnel Center (MPC). However, this data base had two major problems which precluded its use.

First, the file contains data from about Fiscal Year (FY) 1969 to the present. For a one-year interval, this translates to only seven data points at best. In a regression equation with only three independent variables, three degrees of freedom would be available for estimating variance. This was judged insufficient. The second problem was one of variable record lengths even for personnel with the same year of entry. For example, two officers both entering the Air Force in FY 1970 could have records in the file starting in FY 1970 and FY 1971 respectively. Thus a sample in any given fiscal year would likely contain only a fraction of the rated force. The extent of this problem was unknown but its existence together with the sample-size problem were sufficient to warrant a search for alternative data sources.

Data on Rated Officers Actively Flying

This search for available data ultimately led to the Management Summary series of documents prepared by the offices of the Directorate of Management Analysis, Headquarters USAF (HQ USAF 1975; HQ USAF 1976). Annually this organization prepares a statistical summary of information of possible interest to USAF personnel. These documents, titled "USAF Statistical Digest," contain among other things, data relating to the rated officer force (HQ USAF 1976). The data closest to what was needed for this study were tables of crews "formed" by type of aircraft. Tables were available for several years into the past and cited the FORSTAT data base as their sources. The FORSTAT data base, fortunately, has existed for a substantially longer period than the Master Personnel File. It was established by and is maintained by the Office of the Joint Chiefs of

Staff (OJCS) and is well documented (Joint Chiefs of Staff 1974). The definition of a "formed crew" provided by the OJCS is:

> A group of crew members -- constituted as a crew and designated as such by an appropriate official document, as determined by the major commander. A formed crew must be technically qualified to fill a crew position for the performance of the organization's primary mission.

Thus, the FORSTAT data provided in these annual statistical digests seemed appropriate for use in this study. They also provided a logical separation between rated officers involved in active flying and those who were not. However, the data necessitated collecting still more data. Namely, it was necessary to find the number of pilots and navigators <u>per crew</u> of each type aircraft in the active inventory for each year under study. Fortunately, these additional data were available in several aircraft characteristics documents (Aeronautical Systems Division 1975). The data gathered from these documents are presented in Table I below.

Use of the aircrew data described above involves several implicit assumptions. As aircraft were produced, later models incorporated important configuration changes. Occasionally the changes involved adding an additional cockpit position. For example, the F-100F (the last model built) had two seats while all previous models had only one. The F-105F and F-105G aircraft also had this property. The assumption made in cases like these was that the additional seats provided by these later models were negligible when considered with the total number of aircraft produced. Therefore, by this assumption, the number of pilots and navigators per crew were constant over time and only the number of crews formed varied.

An important change occurred in the pilot/navigator crew composition for the F-4 aircraft. In this aircraft what changed was the way in which

Table I

Pilots and Navigators per Crew by Aircraft Type

Aircraft	Pilots	Navigators	Aircraft	Pilots	Navigators
B-47	2	1	F-4	2	0
B-52	2	2	F-5	1	0
B-58	1	1	F-15	1	0
FB-111	1	1	F-16	1	0
			F-84	1	0
KC-97	2	2	F-86	1	0
KC-135	2	1	F-100	1	0
			F-101	1	0
A-1	2	0	F-102	1	0
A-7	1	0	F-104	1	0
A-10	1	0	F-105	1	0
A-37B	2	0	F-106	1	0
B-57G	1	1	F-111	1	0
SR-71	1	0	O-1	1	0
RB-57	1	0	O-2	1	0
RF-4	1	1	OV-10	1	0
RF-101	1	0			
			C-5	2	1
EB-57	1	0	C-7	2	0
EB-66	1	1	C-9	1	1
EC-47	2	1	C-47	2	1
EC-121	2	1	C-97	2	1
EC-135	2	1	C-123	2	0
EF-111	1	0	C-124	2	1
			C-130	2	0
			C-141	2	1

the Air Force chose to use the two seats available. This change must be taken into account because of the preponderance of F-4 aircraft in the fighter inventory for several years. For this aircraft, the two seats were filled by pilots until FY 1966, at which time a gradual change to one pilot and one navigator was initiated. This change lasted for about three years until FY 1968 when all F-4 crews had one pilot and one navigator. Policy during this changeover period was such that the shift was essentially linear (Harrell 1976, Henry 1976). Therefore, a linear changeover was assumed.

Given the data on the number of crews formed and the number of pilots and navigators per crew, what remained was merely to multiply the two and sum to determine the number of pilots and navigators engaged in active flying by weapon system. However, the apparent simplicity of this approach created several problems which are described below. The resulting data are also presented in a summary section.

<u>Data on Rated Officers Not Actively Flying</u>

Those rated officers not engaged in day-to-day flying (not in formed crews) were grouped into five categories: Undergraduate Pilot Trainees (UPT's), Undergraduate Navigator Trainees (UNT's) those attending AFIT, those attending Professional Military Education schools (PME), and those in the rated supplement. Data were collected from several sources to distribute these officers among the categories (Collier 1976, AFIT/DP 1976, Castle 1976). Unfortunately no source was available for the number of officers in the rated supplement. So this category was determined by subtracting the total of all other categories from the total rated inventory for each year (HQ USAF 1975).

Aircraft Data

Historical force structure information was found from two independent sources (U.S. Congress 1975; HQ USAF 1976). These sources agreed nearly to the individual number, even though the data were aggregated into broad categories of aircraft. Table II below, shows the data used in the analysis. Following some initial work, it was desired to separate strategic and tactical airlift aircraft. The data to permit this were found in statistical summaries prepared at Headquarters, Military Airlift Command (MAC) (HQ MAC 1959-1976). These data are shown in Table III below.

Problems and Necessary Assumptions

Translating the raw data to a useable form required several new assumptions. Again these assumptions are logically grouped for discussion.

Assumptions regarding active flyers. The most common problem requiring either an assumption or additional data was that of lumping. That is, the data on crews formed by aircraft type were occasionally aggregated over several aircraft types. This in itself presented no problem unless the numbers of pilots or navigators per crew differed among the lumped aircraft. However, if crew complements differed, an assumption was made which involved a proportionality between the aircraft and the crews. A hypothetical example is given below to illustrate the method:

Given: 1. Crews formed in CX-1 and CX-2 aircraft - 120

2. CX-1 aircraft in the inventory - 50

3. CX-2 aircraft in the inventory - 50

Table II

USAF Active Aircraft Inventory

Fiscal Year	Bombers	Tankers	Recon-naissance	Fighter Attack	Cargo	Trainer	Other	Total
1959	2229	1190	887	4980	2788	4268	1010	17352
1960	2193	1230	685	3922	2549	3914	819	15312
1961	1946	1265	616	3457	2396	3413	796	13889
1962	1851	1258	721	2895	2504	3429	804	14462
1963	1674	1100	655	3718	2510	3159	864	13680
1964	1509	998	595	3538	2327	2873	849	12689
1965	1245	832	538	3643	2366	2782	874	12280
1966	845	697	732	3520	2266	2646	1004	11710
1967	818	677	858	3602	2347	2599	1163	12064
1968	779	667	1009	3985	2358	2584	1224	12606
1969	732	662	1063	3825	2087	2744	1089	12202
1970	570	663	993	3404	1854	2625	1112	11221
1971	622	662	841	3082	1583	2623	1008	10421
1972	558	660	750	2652	1325	2454	856	9255
1973	520	660	687	2552	1175	2271	673	8538
1974	500	657	610	2387	1253	1996	527	7930
1975	498	657	494	2299	927	1861	503	7239
1976	422	621	411	2495	884	1808	480	7123

Table III

Tactical and Strategic Airlift Aircraft Inventory

Fiscal Year	Tactical Airlift Aircraft	Strategic Airlift Aircraft	Total Cargo Aircraft
1959	2210	578	2788
1960	1854	695	2549
1961	1870	526	2396
1962	1895	609	2504
1963	1925	585	2510
1964	1731	596	2327
1965	1785	581	2366
1966	1708	558	2266
1967	1848	499	2347
1968	1811	547	2358
1969	1724	363	2087
1970	1537	317	1854
1971	1269	314	1583
1972	1003	322	1325
1973	933	342	1175
1974	911	342	1253
1975	597	340	937

Assumption: Half the crews formed (60 crews) were in CX-1 aircraft. In short, the number of crews formed in an aggregate category over several aircraft was distributed just as the aircraft were.

The other difficulty with raw data in this particular category could be termed anomalies. Several data points simply didn't make sense in light of other data. For example, for three successive years crews formed of 1400, 19, and 1350 arouses suspicion regarding the 19. Assumptions were therefore necessary to remove these anomalies.

The list of those assumptions made is presented explicitly in Table IV below.

Table IV

Data Assumptions Necessary Regarding Active Flyers

Half of the B-58 crews formed in FY 1966 were formed in FY 1965.
For FY 1973 and FY 1974, there were 1.8 pilots and 1.8 navigators and 2.0 pilots and 2.0 navigators in B-52/B-58 aircraft (lumped), respectively.
During the period FY 1971 to FY 1975, the EB-66 and EC-47 crews formed decrease at the same rate.
An Airlift Service Industrial Fund (ASIF) aircraft crew (Strategic airlift) consists of two pilots and one navigator; the non-ASIF aircraft crew consists of two pilots and no navigators.
A Special Operating Forces (SOF) aircraft crew consists of 1.2 pilots and no navigators.
The ratio of B-52 to FB-111 crews formed in FY 1972 remained the same in FY 1973 through FY 1975.
There were 500 C-141 crews formed in FY 1974.

Assumptions Involving Nonflying Rated Officers. Putting these data in useable form also required several assumptions. For example, the available data for rated officers attending Professional Military Education (PME) schools included flight surgeons, flight nurses and observers. The data were also aggregated so that pilots and navigators were indistinguishable. Data available in the AFIT category were graduates by calendar year rather than attendees by fiscal year. Since the loss rate for nongraduate AFIT students was quite low (AFIT/RR 1976), all that was involved here was an assumption about average AFIT tour length. The necessary assumptions for these categories are listed in Table V.

Table V

Assumptions Necessary for Data on Rated Officers Not Actively Flying

The number of observers, flight surgeons, and flight nurses who attended PME schools was negligible.
The fractions of total PME attendees which were pilots and navigators were the same as the fractions of total rated officers which were pilots and navigators, respectively.
For purposes of PME attendees, the difference between calendar year and fiscal year is negligible.
The average tour length of (any) student is 18 months beginning in the month of June.

Summary Tables

The results of this rather large data-collection effort are summarized in the two tables that follow (Table VI and Table VII). The data in them constitute the data base used in subsequent regression analyses.

Table VI

Historical Distribution of the Pilot Force

Fiscal Year	Pilot Category 1	2	3	4	5	6	7	8	9	10	11
1959	5002	2834	4281	480	1750	982	*	*	*	*	*
1960	5364	3088	3219	389	1482	1066	*	*	*	*	*
1961	4659	3196	3170	396	1456	1040	*	*	*	*	*
1962	5067	3330	3751	438	1588	908	*	*	*	*	*
1963	4317	2954	3433	350	1544	968	*	*	*	*	*
1964	3843	2886	2434	365	1516	1274	197	*	2195	1613	*
1965	3183	2792	2638	370	2334	1200	445	1155	2165	1441	30120
1966	2081	2352	2609	416	2382	1540	681	903	*	1053	*
1967	1849	1946	2679	360	1812	1880	1141	691	3553	555	28063
1968	1606	1804	3002	479	2340	1750	1398	712	3429	297	26815
1969	1274	1598	2506	331	1578	1626	1603	601	3971	378	27310
1970	1070	1602	2142	331	1446	1772	1393	479	4402	464	25303
1971	1097	1600	1669	280	1368	1620	1113	463	3910	829	26198
1972	1677	2444	1688	258	1234	1118	896	548	2839	1051	26302
1973	1126	1634	1435	263	1042	592	637	682	2319	1070	26519
1974	1164	756	1535	233	1000	474	478	669	2035	1453	24433
1975	983	894	1413	220	920	460	417	566	1774	1432	23040

Pilot Category Codes

1. Bombers
2. Tankers
3. Fighter/Attack
4. Reconnaissance
5. Strategic Airlift
6. Tactical Airlift
7. Other Aircraft
8. Pilots attending AFIT
9. UPTs
10. Pilots attending PME
11. Rated supplement

*The data in these categories for these years were not available.

Table VII

Historical Distribution of the Navigator Force

Fiscal Year	Navigator Category 1	2	3	4	5	6	7	8	9	10	11
1959	3048	1417	0	0	875	0	0	*	*	*	*
1960	3453	1544	0	0	741	0	0	*	*	*	*
1961	3237	1598	0	0	728	0	0	*	*	*	*
1962	3607	1665	0	0	794	0	0	*	*	*	*
1963	3234	1477	0	0	772	0	0	*	*	*	*
1964	3013	1443	40	41	758	0	0	*	815	629	*
1965	2666	1396	60	76	1167	0	0	523	740	575	11494
1966	2081	1176	54	121	1191	0	6	560	*	433	*
1967	1849	923	76	126	906	0	35	463	627	229	12457
1968	1606	902	382	163	1170	0	199	484	650	119	11313
1969	1274	799	620	97	789	0	114	528	792	150	11263
1970	1070	801	829	118	723	0	162	457	743	182	10219
1971	1097	800	1273	264	684	0	144	383	1008	317	8915
1972	1677	1222	1342	242	617	0	84	359	1042	396	7711
1973	1126	817	809	249	521	0	140	358	1013	416	8866
1974	1164	378	911	222	500	0	102	315	953	578	8657
1975	983	447	837	209	460	0	92	228	739	607	9258

Navigator Category Codes

1. Bombers
2. Tankers
3. Fighter/Attack
4. Reconnaissance
5. Strategic Airlift
6. Tactical Airlift**
7. Other Aircraft
8. Navigators attending AFIT
9. UNT's
10. Navigators attending PME
11. Rated supplement

*The data in these categories for these years were not available.

**This category was included for consistency with the preceding table even though there was no need for it. There were no navigators in tactical airlift aircraft by assumption.

III. DEVELOPING RELATIONSHIPS AMONG VARIABLES

This chapter describes the details of the approach taken to develop analytical relationships among the pilot and navigator variables and certain "explanatory" variables used in the analysis. First a brief description is presented of the Standard Linear Model used in the analysis stressing the assumptions of this model as they relate to the problem at hand. The model will be described in terms of its application to the variables used in this analysis. Following this are the results of applying this model to each of the categories of pilots and navigators described in the preceding chapters. For each category (model), the development of a suitable model is traced, the resultant analytical form is presented, problems of application and their respective resolutions are discussed, and finally any inferences that can be drawn are described. The major hypothesis of this thesis which underlies the development of each model presented is that the numbers of pilots and navigators in active flying categories are linear functions of the numbers of aircraft in the same categories. This theme pervades the remainder of this chapter. The final section of this chapter provides a summary of the models developed and draws some overall inferences of possible interest to manpower planners.

Study Context of the Standard Linear Model

In this section the use made of the Standard Linear Model is described. It is intended only to relate the model to the problem at hand and not to develop the model in detail. Many fine sources of information regarding this model exist (Theil 1971, Johnston 1972, Mendenhall and Schaeffer 1973). The basic reference used for this effort was

Theil (1973). The notation used herein is the same as in that text.

Form of the Standard Linear Model. As used in this thesis, the model is of the form: $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \text{---} + \beta_k x_k + \varepsilon$ where the β_i, i = 0, 1....k are unknown parameters, the x_i, i = 1, 2, --- k are known with certainty and ε is a random variable with mean zero. Using this model, we then make n independent observations of y and x_i, i = 1 --- k. We will use matrix algebra to describe the resulting n equations in k unknowns (the β_i) as $\underline{y} = X\,\underline{\beta} + \underline{\varepsilon}$ where $\underline{y}$ is an n x k matrix of observations of the k independent variables; $\underline{\beta}$ is a k x 1 vector of unknown parameters (coefficients); and $\underline{\varepsilon}$ is an n x 1 random vector of "disturbances" or "errors."

In our formulation we view $\underline{y}$ as an observation vector of the number of pilots (or navigators) in some category. The matrix X consists of observations on k independent or "explanatory" variables the primary one being aircraft in the same category. The vector $\underline{\varepsilon}$ is viewed as a vector of random errors introduced by manpower planners as they attempt to man these aircraft with qualified rated officers from year to year.

Assumptions of the Standard Linear Model. Of particular interest in applying the Standard Linear Model is the extent to which the following assumptions are satisfied. In fact, many of the problems discussed in later sections deal with these assumptions and the aptness of the model to the data at hand.

The first assumption involves the expectation of the dependent variable:

$$E(\underline{y}|X) = X\underline{\beta}$$

or equivalently

$$E(\underline{\varepsilon}|X) = \underline{0}$$

This says that the expected value of the random vector $\underline{y}$ is (exactly) equal to the set of simultaneous linear equations, $x\underline{\beta}$. In our context the interpretation is that the number of pilots (or navigators) observed in a given category over time (n periods) are realizations of an n-element random vector whose expected value (conditional on X) is $X\underline{\beta}$. The disturbance formulation, $E(\underline{\varepsilon}) = \underline{0}$, is more intuitively appealing. We interpret $\underline{\varepsilon}$ as error introduced by manpower planners attempting to adequately man the aircraft force with qualified rated officers --- to "bridge the gap" from requirements to authorizations to possessions (men in place). We are saying that the mean of this error introduced is zero.

The second assumption is usually referred to as a scalar covariance matrix:

$$\mathrm{Var}\ (\underline{y}|X) = \sigma^2 I$$

where σ^2 is an unknown parameter and I is the n x n identity matrix. Equivalently we may write:

$$\mathrm{Var}\ (\underline{\varepsilon}|X) = \sigma^2 I$$

Again in our context, this means that the variance of the dependent variable (numbers of pilots or navigators in a given category) is the same in each year of observation. We might say that manpower planners have missed "bridging the gap" by the same spread each year since 1959. This could be interpreted broadly to be an assumption about the collective abilities of manpower planners at MPC since the tools at their disposal have remained largely unchanged since then.

The third and final assumption is technically not a part of the Standard Linear Model but is usually closely associated with it. The

assumption is simply that $\underline{y}$ has a multinormal distribution with mean $X\underline{\beta}$ and variance $\sigma^2 I$. Again, the equivalent disturbance formulation is that $\underline{\varepsilon}$ is multinormal with mean $\underline{0}$ and variance $\sigma^2 I$. Relating this to our formulation, we are saying the number of pilots (or navigators) in a given category is normally distributed. This assumption presents an immediate problem. The domain of definition of a normal random variable is $(-\infty, +\infty)$. This is certainly not a reasonable domain of definition for the number of pilots or navigators in a given category. However, the condition is partially relieved by observing that the means in each category are large relative to their variances so that negative values will occur only over a small part of the assumed distribution. So the normality assumption is not violated too badly on this count alone. We might say that the assumption is satisficed (Albanese 1975) for our purposes.

Problems with the Standard Linear Model. The basic problems to be anticipated in using the Standard Linear Model for this analysis involve satisfying (or satisficing) the above assumptions.

The potential problem with the first assumption is one of specification. That is, are all of the relevant independent variables included in the matrix X? For this study, the extent to which this condition holds is estimated through the multiple correlation coefficient, R^2 (Theil 1971).

Assumption two can be violated in a number of ways. The condition of nonconstant variance of $\underline{\varepsilon}$, or heteroscedasiticity, can be tested statistically. For this analysis, however, the condition was tested first visually by observing a plot of standardized residuals against predicted values. Nonrandom patterns in these plots were interpreted as

indications of heteroscedasticity (Hogben et. al. 1971). In the context of time-series analysis (which this study is), the most common variety of nonscalar covariance is termed autocorrelation. This term refers to correlations between successive time-series "observations" of the individual error terms ε. In this study, the autocorrelation condition is tested in two ways:

The Durbin-Watson Test (Durbin and Watson 1951).

The Runs Test (Mendenhall and Schaeffer 1973).

The latter is used when sample size does not permit use of the Durbin-Watson Test. When Durbin and Watson developed their test for autocorrelation, they chose to terminate tabulation of values at a sample size of $n = 15$. The test involves a region for the test statistic, D, within which the test is inconclusive. This uncertain region grows with decreasing sample size. Since below $n \approx 15$ the region can grow quite large, it is obvious that this value was chosen by Durbin and Watson as a reasonable stopping point.

Violation of assumption three, the normality assumption, can be detected through analysis of the residuals of each regression. One of the better ways of detecting deviations from normality is visually. If one plots standardized residuals of each regression on normal probability paper, significant departures from a straight line can be interpreted as departures from normality (Neter and Wasserman 1974). This approach was used here as an initial screening device to detect nonnormality. If nonnormality was found in this visual manner, further statistical tests were performed in order to verify the result more rigorously (e.g. Chi-Square Goodness of Fit Test) (Mendenhall and Schaeffer 1973).

Development of the Models

For purposes of presentation in this section, each of the models developed are described in a different order than that found in Chapter II. The models for categories of the pilot force are presented first in the following order: Bomber, Tanker, Fighter/Attack, Reconnaissance, Airlift, Other Aircraft, AFIT attendees, UPT's, PME attendees, and Supplement. Following these, the models for categories of the navigator force are presented in the same order. For the first six categories of both pilots and navigators, the independent variable of most interest, of course, is the number of aircraft in the same category.

For each of these models below, care must be exercised in interpreting the intercept term of the resulting equation. The term was included to permit variation in the slope of the fitted regression line. Regression through the origin, although intuitively appealing here, carries with it a greater risk of error if the true relationship is nonlinear (Neter and Wasserman 1973). If the constant term is included as it was in the models that follow, then the resulting regression can be viewed as linear within the range of the data. For this reason, the means of all independent variables are included to "place" the regression equation. Finally, for each model developed, a visual "feel" for the nature of the regression can be obtained from a plot of the raw data and the fitted regression line. These plots are contained in Appendix A in the same order as in this chapter.

Bomber Pilots. This model offers the most striking evidence to support the overall hypothesis of this thesis. The initial simple regression using only bomber aircraft (and a constant term) produced an R^2 value of 0.97. The resultant regression equation and other relevant data are in the following table:

Table VIII

Bomber Pilot Model

Equation	:	$y = -224 + 2.58\ x_1$
Variables	:	y - number of bomber pilots
		x_1 - number of bomber aircraft
Means	:	$\bar{x}_1 = 1123$
Sample Size	:	n = 17
R^2 coefficient	:	0.97
Durbin-Watson Statistic	:	1.37
F Statistic ($\underline{\beta} = \underline{0}$)	:	528.7
t Statistic ($\beta_1 = 0$)	:	23.0

The regression showed no significant evidence of violating any of the assumptions of the Standard Linear Model. The Durbin-Watson statistic falls in the region implying no positive autocorrelation. The statistic (4 - D) = 2.63 falls in the region implying no negative autocorrelation. An F statistic of this size indicates a rather high confidence that $\underline{\beta} \neq \underline{0}$ since F(.01, 2, 15) = 6.36. Finally, the t statistic shows a significance level well below one percent t(.005, 15) = 2.95 for the hypothesis that β_1 (the coefficient of x_1, bomber aircraft) is zero.

Further attempts to refine the model and find more significant variables were fruitless as expected. The two variables examined were total aircraft and an indicator variable for the Vietnam conflict. This latter variable was valued at zero for years when the Vietnam conflict was not active and at 1.0 for years when it was active. The "beginning" year was based on the first significant buildup of U.S. forces (Tolson 1973) and the ending year on the date the last combat troops left Vietnam (11 August 1972). This information (as well as the beginning date) was found in the 1975 World Almanac. Neither this indicator variable nor the total aircraft variable were significant at the five-

(or one-) percent significance level. The respective t statistics were -0.51 and -1.95.

Tanker Pilots. This model required somewhat more exploration than the first model. Initial trials of the basic hypothesis involved equations which were linear in both the independent variables and the coefficients. These produced results which violated many assumptions and had R^2 coefficients of at most 0.60. Subsequent examinations led to nonlinear forms for the independent variables which involved diminishing marginal increases. Both an inverse and a square root term were examined and the latter was selected. The results follow.

Table IX

Tanker Pilot Model

Equation	:	$y = -4567 + 222\, x_1 + 757\, x_2$
Variables	:	y - number of tanker pilots
		x_1- square root of the number of tanker aircraft
		x_2- Vietnam indicator variable
Means	:	$\bar{x}_1 = 29.0$
		$\bar{x}_2 = 0.471$
Sample size	:	n = 17
R^2 coefficient	:	0.86
Durbin-Watson Statistic	:	1.251
F Statistic ($\underline{\beta} = \underline{0}$)	:	13.81
t Statistic ($\beta_1 = 0$)	:	8.84
($\beta_2 = 0$)	:	3.72

This regression did not show significant departures from any assumptions either. The D statistic implies no positive (or negative) autocorrelation. The F statistic leads us to reject the hypothesis that $\underline{\beta} = \underline{0}$ (F = 3.34). Finally, both coefficients were significant at the one percent level (t = 2.95).

It is interesting to note both the significance and the influence of the Vietnam indicator variable x_2. The interpretation of the coefficient of x_2 is that the presence of Vietnam ($x_2 = 1$) added 757 pilots to the tanker pilot force. This indicates that another Vietnam-type conflict would demand a shift in the distribution of the pilot force which involved increasing tanker pilots by 757.

Fighter/Attack Pilots. This model required the addition of an additional independent variable. Since Fighter/Attack aircraft had a large F-4 component, the policy decision to place navigators in F-4's was expected to influence the model for this category (see Chapter II). The variable chosen represented the fraction of the F-4 aircraft force which had navigators flying in them. As expected, this variable was statistically significant. The model is described in Table X.

Table X

Fighter/Attack Pilot Model

Equation	: $y = 71.3 + 0.86\ x_1 - 716\ x_2$
Variables	: y - fighter/attack pilots
	x_1- fighter/attack aircraft
	x_2- fraction of the F-4 aircraft with navigators flying in them
Means	: $\bar{x}_1 = 3439$
	$\bar{x}_2 = 0.647$
Sample size	: n = 17
R coefficient	: 0.93
Durbin-Watson Statistic	: 1.62
F Statistic ($\underline{\beta} = \underline{0}$)	: 21.8
t Statistic ($\beta_1 = 0$)	: 8.21
($\beta_2 = 0$)	:-4.67

Interpretation of the coefficient of x_2 is that the policy decision to move navigators into F-4 aircraft produced a decrease of 716 pilots in

the Fighter/Attack force on the average. Again the D statistic implies no autocorrelation, the F statistic indicates model significance and the respective t statistics indicate significance of the model parameters at the one percent level.

Subsequent tests of the Vietnam indicator variable provided insufficient evidence to permit rejecting the hypothesis that its coefficient was zero.

Reconnaissance Pilots. This model did not support the basic hypothesis of this thesis: that pilots (or navigators) in a category are primarily a function of aircraft in that category. In fact, trials of the hypothesis produced very small R^2 values. The variable that did prove significant was total USAF aircraft. The results follow in Table XI.

Table XI

Reconnaissance Pilot Model

Equation	:	$y = 41.5 + 0.025\ x_1$
Variables	:	y - reconnaissance pilots
	:	x_1 - total USAF aircraft
Means	:	$\bar{x}_1 = 11{,}932$
Sample size	:	$n = 17$
R^2 coefficient	:	0.75
Durbin-Watson Statistic	:	$D = 2.02$
F Statistic ($\underline{\beta} = \underline{0}$)	:	45.8
t Statistic ($\beta_1 = 0$)	:	6.77

Again there was no striking evidence of violation of the assumptions. The D statistic implies no autocorrelation and the F statistic implies significance at the one percent level. Finally the t statistic for x_1 indicates significance at the one percent level. Note that

with this model, the effects of Vietnam proved insignificant. The result above implies that aircraft types other than reconnaissance also had an effect on reconnaissance pilots. Since the bulk of this aircraft force is RF-4's, one of these other aircraft could be the F-4.

Airlift Pilots. Initial attempts to define this model used data aggregated over both varieties of airlift pilots (aircraft): tactical airlift and strategic airlift. The former category refers to aircraft commonly used to deliver supplies to forward-area bases in wartime while the latter category involves aircraft delivering supplies to main operating bases in the theater from the U.S. These attempts produced R^2 coefficients on the order of 0.5. Later addition of the Vietnam indicator variable proved quite significant for the overall airlift case. However, in the interim, several trials were examined where tactical and strategic airlift were separated into two models. These proved to be slightly better, considering all the assumptions, than the combination model. The results are described in the following two tables.

Table XII

Strategic Airlift Pilot Model

Equation	:	$y = -32.5 + 2.73\, x_1 + 650\, x_2$
Variables	:	y - strategic airlift pilots
		x_1 - strategic airlift aircraft
		x_2 - Vietnam indicator variable
Means	:	$\bar{x}_1 = 477$
		$\bar{x}_2 = 0.471$
Sample Size	:	$n = 17$
R^2 coefficient	:	0.85
Durbin-Watson Statistic	:	$D = 2.55$
F Statistic ($\underline{\beta} = \underline{0}$)	:	48.8
t Statistic ($\beta_1 = 0$)	:	7.41
($\beta_2 = 0$)	:	6.98

For this model, again there was no significant evidence of violation of the assumptions. The D statistic implies no autocorrelation; the F statistic implies nonzero coefficients; and the coefficients b_1 and b_2 are significant at the one percent level. Note again the influence of the Vietnam conflict: an increase in strategic airlift pilots of 650.

Table XIII

Tactical Airlift Pilot Model

Equation	:	$y = 104 + 0.49\, x_1 + 490\, x_2$
Variables	:	y - tactical airlift pilots
		x_1- tactical airlift aircraft
		x_2- Vietnam indicator variable
Means	:	$\bar{x}_1 = 1565$
		$\bar{x}_2 = 0.471$
Sample size	:	$n = 17$
R^2 coefficient	:	0.80
Durbin-Watson Statistic	:	D = 2.56
F Statistic ($\underline{\beta} = \underline{0}$)	:	28.3
t Statistic ($\beta_1 = 0$)	:	4.80
($\beta_2 = 0$)	:	5.32

There was no evidence of assumption violation. The various statistics indicate no autocorrelation and significance at the one percent level for the parameters both singly and collectively. The effect of the Vietnam conflict (assuming all other things being equal) was an increase of 490 tactical airlift pilots.

<u>Other Aircraft Pilots</u>. Development of this model was straightforward although it was limited by a smaller sample size than previous models. The model also tends to support the primary hypothesis although not as strongly.

Table XIV

Other Aircraft Pilot Model

Equation	:	$y = 455 + 2.83\ x_1 - 0.20\ x_2$
Variables	:	y - other aircraft pilots
		x_1- other aircraft
		x_2- total USAF aircraft
Means	:	$\bar{x}_1$- 948
		$\bar{x}_2$- 10,679
Sample Size	:	n = 12
R^2 coefficient	:	0.82
Durbin-Watson Statistic	:	D = 1.56
F Statistic ($\beta = 0$)	:	11.3
t Statistic ($\beta_1 = 0$)	:	5.77
($\beta_2 = 0$)	:	3.36

The regression indicated no significant departures from the assumptions. The F and t statistics all indicate a one percent significance level. The Durbin-Watson statistic is still meaningful for the sample n = 12 even though the relevant tables extend to only n = 15. At a sample size of 15, the value of D_U is 1.25 (Theil 1971) and descending with smaller sample sizes. From this we can conclude that at n = 12, $D_U \leq 1.25$ and our test statistic is in the region indicating no autocorrelation.

Addition of the Vietnam indicator variable to this model was not significant (t = 0.14). That is, one cannot reject the hypothesis that this coefficient is zero. From this we can infer that pilots of "Other Aircraft" were not influenced by the Vietnam conflict.

Note the presence and significance of the variable x_2, total USAF aircraft. This means that for this model, aircraft in the category did not have as strong an influence on pilots in the category as observed in previous models. The variable x_2 was needed to increase the significance of the regression.

Pilots attending AFIT. For this model, it was known at the outset that no aircraft were involved. In addition, this is the second of our models which had a reduced sample size (n = 12). Thus the primary hypothesis of this thesis could not be tested with this model. Some other explanatory variables had to be found. Since the output of AFIT is both rated and nonrated officers with advanced degrees (of use to the Air Force), then AFIT entrants in any category should be influenced by the need for these officers. This need for officers with advanced degrees depends in part on the pace of technology, which in turn should depend in part on what money is spent on advancing technology. This rationale led to selecting three variables for exploration:

1. The U. S. Gross National Product -- a surrogate measure of what the country has to offer toward advancing technology (among other things).

2. Air Force funds (outlay) provide for research and development -- a measure of what the Air Force devotes to advancing technology (among other things).

3. Total Air Force Outlays -- a measure of what the Air Force has to offer toward advancing technology (among other things).

Of these three variables, the last proved to be most significant. Results of this regression are shown in Table XV. The Durbin-Watson statistic is greater than the tabled D value at n = 15. From this we conclude no significant autocorrelation. Both F and t statistics show significance at the one percent level. Finally, the interpretation

of the independent variable is that every dollar increase in Air Force outlays leads to a decrease of 71 pilots attending AFIT, precisely the opposite result from that expected. What this could mean is that increasing relative Air Force "prosperity" creates increasing demand for flying operations which creates increasing demand for pilots in flying jobs; hence the decrease in pilots attending AFIT.

Table XV

Model for Pilots Attending AFIT

Equation	: $y = 2339 - 71\ x_1$
Variables	: y - pilots attending AFIT
	: x_1- Total Air Force outlays (billions)
Means	: $\bar{x}_1 = 25.4$
Sample Size	: n = 12
R^2 coefficient	: 0.73
Durbin-Watson Statistic	: D = 1.23
F Statistic ($\underline{\beta} = \underline{0}$)	: 27.3
t Statistic ($\overline{\beta}_1 = \overline{0}$)	: -5.22

Addition of the Vietnam indicator variable proved not significant (t = -0.30). This is interpreted to mean that the Vietnam conflict (surprisingly) had no significant effect on pilots attending AFIT.

Undergraduate Pilot Trainees. For this model it was expected that deficiencies in the number of pilots actively flying would produce demand for UPT graduates and thus UPT's. In addition, any variables which measured the causes of these deficiencies might be expected to increase demand for UPT's. For these reasons, two variables were tested which could be interpreted to measure deficiencies in the actively flying force of pilots:

1. The ratio of total pilots to total aircraft -- the theory here was that this ratio should have some value (greater than 1.0) which, when reached (from above), would indicate a deficiency.

2. Percent of the pilot force engaged in flying actively -- the theory here was as above except the measure was more direct.

In addition to these, the Vietnam conflict was expected to have a significant influence on the demand for UPT's. The model involving the first variable above, had the largest R^2 coefficient (0.69) but also exhibited autocorrelation and violated the scalar-covariance assumption to some degree. In contrast, the model selected was not far below ($R^2 = .60$) and did not show significant departure from any assumptions. Relevant data are shown in Table XVI.

Table XVI

Model for Undergraduate Pilot Trainees

Equation	:	$y = 3488 + 1575\ x_1 - 72\ x_2$
Variables	:	y - undergraduate pilot trainees
	:	x_1 - Vietnam indicator variable
	:	x_2 - percent of the pilots actively flying
Means	:	$\bar{x}_1 = 0.67$
	:	$\bar{x}_2 = 22.1$
Sample Size	:	$n = 12$
R^2 coefficient	:	0.60
Durbin-Watson Statistic	:	D = 1.68
F Statistic ($\underline{\beta} = \underline{0}$)	:	1.41
t Statistic ($\beta_1 = 0$)	:	3.61
($\beta_2 = 0$)	:	-1.19

This regression was not as "satisfying" as previous ones. That is R^2 was (relatively) smaller, the F statistic did not permit rejecting the hypothesis that $\underline{\beta} = \underline{0}$ and the t statistic did not permit rejectint the hypothesis that $\beta_2 = 0$. Nevertheless, the model was the best to be had and it provided some significant insights as well. First, the Vietnam indicator variable had the most significant effect of all those tested. This was expected since the conflict increased the demand for UPT graduates. Second, for each percentage point increase in the x_2 variable, an implied decrease of 72 pilots occurs. This says that a current increase in active flyers produces a decrease in the future demand for active flyers (current UPT's) -- a statement with intuitive appeal.

Pilots Attending PME Schools. This model contains only independent variables previously used in other models and is also limited to a sample size of n = 12. For this model, a rationale similar to the result of the AFIT pilot model was tested. That is, the number of pilots attending PME schools (presumably a desirable thing for pilots to do) is influenced by the relative need for pilots in flying jobs. The greater the need, the fewer the number of pilots in PME. The results generally confirmed this hypothesis even though the model selected did not involve variables of this sort. There was no evidence of assumption violation for this model. Again the D statistic is in the region implying no autocorrelation even though the sample size is 12. The F statistic and all t statistics indicate significance at the one percent level. Note that the Vietnam indicator variable implies a decrease of 638 in pilots attending PME schools because of Vietnam.

Table XVII

Model for Pilots Attending PME Schools

Equation	:	$y = 4048 - 114\, x_1 - 638\, x_2$
Variables	:	y - pilots attending PME schools
	:	x_1- total USAF outlays
	:	x_2- Vietnam indicator variable
Means	:	$\bar{x}_1 = 25.4$
	:	$\bar{x}_2 = 0.67$
Sample Size	:	n = 12
R^2 coefficient	:	0.81
Durbin-Watson Statistic	:	D = 1.92
F Statistic ($\beta = 0$)	:	21.6
t Statistic ($\beta_1 = 0$)	:	-4.08
($\beta_2 = 0$)	:	-4.65

The interpretation for x_1 is that relative Air Force prosperity causes the demand for actively flying pilots to rise. Attendant to this rise in demand is a decrease in opportunity for pilots to attend PME schools. Our model says that the extent of the decrease for every billion dollars of increase in the Air Force's prosperity is 114 pilots.

Supplement Pilots. For this model, like the one for UPT's, it was expected that deficiencies in active flyers would lead to demand for supplement pilots to return to flying jobs. For this reason, the same variables examined in the UPT model were tested here. Results support the suspicion although not as strongly. There was no evidence of significant departure from any assumptions even though the $R^2 = 0.51$ is somewhat smaller than in most previous models. The D statistic falls in the region indicating no autocorrelation for n = 15 and hence is acceptable. Both F and t statistics permit rejection of their respective hypotheses at the one percent level.

Table XVIII

Supplement Pilot Model

Equation	:	$y = 18152 + 386\ x_1$
Variables	:	y - pilots in the supplement
	:	x_1- percent of the pilots actively flying
Means	:	$\bar{x}_1 = 22.4$
Sample Size	:	$n = 11$
R^2 coefficient	:	0.51
Durbin-Watson Statistic	:	D = 2.13
F Statistic ($\underline{\beta} = \underline{0}$)	:	9.42
t Statistic ($\beta_1 = 0$)	:	3.07

Finally, the model indicates that an increase in the fraction of the pilots actively flying leads to an increase in supplement pilots. This suggests that some relationship is maintained between the actively flying force and the supplement. The bigger the active flying force, the bigger the supplement!

Bomber Navigators. With this model, we turn our attention to the navigator force. Since the rationales used for the pilot categories *a priori* hold for the navigator force, in each of the categories that follow, the corresponding pilot model was tested first. For this category, the appropriate test produced a substantial R^2 coefficient but also an indication of positive autocorrelation. Therefore, the next trial used values of the independent variable which lagged those of the dependent variable by one year. The results were striking. There was no evidence of significant departure from any assumptions. The D statistic indicates no autocorrelation and both F and t statistics are well in excess of that needed for one percent significance. In short,

lagging the independent variable produced a "near perfect" model. Subsequent trial of the Vietnam indicator variable proved insignificant.

Table XIX

Bomber Navigator Model

Equation	:	$y = 353 + 1.48\, x_1$
Variables	:	y - bomber navigators in year α
	:	x_1- bomber aircraft in year α-1
Means	:	$\bar{x}_1 = 1123$
Sample Size	:	$n = 17$
R^2 coefficient	:	0.94
Durbin-Watson Statistic	:	$D = 1.82$
F Statistic ($\underline{\beta} = \underline{0}$)	:	226.6
t Statistic ($\overline{\beta}_1 = \overline{0}$)	:	15.1

What this lagging procedure and its result imply in our context is that more time elapses as manpower planners "bridge the gaps" for navigators than for pilots (in the bomber category). Another (delicate) way of saying it is that pilot manning in bombers receives earlier emphasis than navigator manning.

Tanker Navigators. A similar result of the lagging procedure characterized this model as well. Trials with nonlinear terms proved not as significant as in the tanker pilot model. The results are nevertheless striking. Again, no assumptions were violated significantly. The D statistic implies no autocorrelation and both F and t statistics insure one percent significance. The striking thing about the model is that whatever time delays exist for bomber navigators must also exist for tanker navigators!

Table XX

Tanker Navigator Model

Equation	:	$y = -578 + 1.74\ x_1 + 303\ x_2$
Variables	:	y - tanker navigators in year α
	:	x_1- tanker aircraft in year α - 1
	:	x_2- Vietnam indicator variable (year α).
Means	:	$\bar{x}_1 = 841$
	:	$\bar{x}_2 = 0.471$
Sample Size	:	$n = 17$
R^2 coefficient	:	0.88
Durbin-Watson Statistic	:	$D = 1.79$
F Statistic ($\underline{\beta} = \underline{0}$)	:	11.54
t Statistic ($\beta_1 = 0$)	:	9.70
($\beta_2 = 0$)	:	3.40

Another significant implication from this model is that the Vietnam conflict created an increase of 303 tanker navigators on the average (with no lag). This follows from the increased use of tanker aircraft in that conflict. The tanker pilot model showed a similar increase for pilots.

Fighter/Attack Navigators. This category consists solely of navigators in F-4 aircraft. Since the policy decision in this regard was made in FY 1964, the sample size was limited to $n = 12$. In addition, because of the way in which the data were developed, the variable indicating the fraction of the F-4 force with navigators in them was simply not used. The results follow.

Table XXI

Fighter/Attack Navigator Model

Equation	: $y = 3041 - 0.87\ x_1 + 547\ x_2$
Variables	: y - fighter/attack navigators
	: x_1- fighter/attack aircraft
	: x_2- Vietnam indicator variable
Means	: $\bar{x}_1 = 3290$
	: $\bar{x}_2 = 0.727$
Sample Size	: n = 11
R^2 coefficient	: 0.64
Durbin-Watson Statistic	: D = 0.89
F Statistic (β = 0)	: 4.14
t Statistic (β_1 = 0)	: -3.74
(β_2 = 0)	: 2.04

Except for the somewhat smaller R^2 value, there was no evidence of significant deviation from the assumptions. The Durbin-Watson D Statistic, however falls in the region where the test is inconclusive. This means that some other test had to be found to indicate anything about autocorrelation. As stated above, the test used was the (nonparametric) runs test. The inference to be drawn if the number of runs observed (in the residuals) is either large or small was that there was a significant departure from randomness. This nonrandom characteristic in residuals, if observed, would imply some sort of heteroscedastic condition, presumably autocorrelation. For this model, the test statistic was R = 4. This is not sufficiently small (or large) to warrant rejecting the hypothesis of randomness with a significance level of 0.05. So we accept the hypothesis of randomness and conclude that no autocorrelation exists. But we must do this without knowledge of the probability of a Type II error (accepting randomness when nonrandomness is true). This is because, for this test, such a probability is not meaningful

(Siegel 1956). Nor were the results of the other tests particularly satisfying. The F test permits rejecting the hypothesis that $\underline{\beta} = \underline{0}$ only at the five percent significance level. The t test corresponding to x_2 implies significance at slightly above the five percent level. (The t value for five percent is 2.306.) The one test related to our overall hypothesis, however, was significant at well below the one percent level.

The sign of the coefficient of x_1 was, of course, not expected. However, the coefficient itself was small. One possible explanation is that the addition of fighter/attack aircraft to the force reduces the proportion of that force consisting of F-4s. This then leads to a reduction of the number of navigators needed in the total fighter/attack force. The coefficient of x_2 was expected. It implies that 547 more navigators were needed in F-4 aircraft as a result of the Vietnam conflict.

Reconnaissance Navigators. This model proved identical to the reconnaissance pilot model. Therefore, support for the overall hypothesis was not found. The aggregated variable that was significant was total Air Force aircraft. The results follow.

Table XXII

Reconnaissance Navigator Model

Equation	:	$y = 478 - 0.03\ x_1$
Variables	:	y - reconnaissance navigators
	:	x_1- total Air Force Aircraft
Means	:	$\bar{x}_1 = 10{,}680$
Sample Size	:	n = 12
R^2 coefficient	:	0.60
Durbin-Watson Statistic	:	D = 1.32
F Statistic ($\underline{\beta} = \underline{0}$)	:	15.3
t Statistic ($\overline{\beta_1} = \overline{0}$)	:	-3.91

Again with this model, the only departure from the basic assumptions was a smaller R^2 value. The D statistic falls in the region indicating no autocorrelation. Both F and t statistics indicate significance at the one percent level. The major difficulty with this model is interpreting the sign of the x_1 coefficient. This indicates that for every 33 aircraft added to the Air Force inventory, there was a decrease of one reconnaissance navigator. This relationship makes somewhat more sense when one considers the basic data. Total Air Force aircraft have gradually decreased for the last 12 years (and more). The regression equation thus implies a relative gradual increase in reconnaissance navigators over the same period. This later trend, of course, also follows from the increase in RF-4 aircraft over this period which would lead to an increase in reconnaissance navigators.

Subsequent investigations did not uncover any additional significant independent variables. Notable among those variables examined was the Vietnam indicator variable.

Airlift Navigators. For this category, navigators were usually found only in strategic airlift aircraft. The only exceptions to this rule occurred in the earlier years of the Airlift Service Industrial Fund (ASIF) and involved aircraft used in both tactical and strategic roles (e.g. the C-47). In addition, the distinction between these roles was not as clear in these early years. For these reasons, independent variables relating to both strategic airlift aircraft and total airlift aircraft were examined. The results are provided in the table below. No evidence existed to suggest any violation of the assumptions; the D statistic implies no autocorrelation and all the test statistics indicate significance at the one percent level.

Table XXIII

Airlift Navigator Model

Equation	:	$y = 125 + 0.27\ x_1 + 230\ x_2$
Variables	:	y - (Strategic) Airlift Navigators
	:	x_1- total airlift aircraft
	:	x_2- Vietnam indicator variable
Means	:	$\bar{x}_1 = 2042$
	:	$\bar{x}_2 = 0.471$
Sample Size	:	$n = 17$
R^2 coefficient	:	0.75
Durbin-Watson Statistic	:	$D = 1.71$
F Statistic ($\underline{\beta} = \underline{0}$)	:	16.1
t Statistic ($\beta_1 = 0$)	:	5.25
($\beta_2 = 0$)	:	4.01

We see that the model supports the basic hypothesis "best" when viewed in the more aggregate context of total airlift. This was true even though the aircraft requiring navigators were in the strategic-airlift category. This implies that tactical airlift aircraft "explained" some of the variance in strategic airlift navigators. This observation is reasonable since strategic airlift aircraft provide a large portion of the workload of tactical airlift aircraft. Thus any increase in the latter will put more demands on the strategic airlift fleet and thereby increase the demand for navigators in that fleet.

Finally, we note the influence of the Vietnam conflict: an increase of 302 navigators. This increase was, no doubt, caused by increases in strategic airlift utilization rates during this period.

Other Aircraft Navigators. This model is the least significant of those in the navigator categories thus far. The data simply do not produce strong results. Nevertheless, the model does support the basic hypothesis of the thesis although weakly.

Table XXIV

Other Aircraft Navigator Model

Equation	:	$y = 238 + 0.33\ x_1 - 0.04\ x_2$
Variables	:	y - other aircraft navigators
	:	x_1- other aircraft
	:	x_2- Total USAF aircraft
Means	:	$\bar{x}_1 = 948$
	:	$\bar{x}_2 = 10{,}679$
Sample Size	:	n = 12
R^2 coefficient	:	0.49
Durbin-Watson Statistic	:	D = 1.88
F Statistic ($\underline{\beta} = \underline{0}$)	:	8.05
t Statistic ($\beta_1 = 0$)	:	2.73
($\beta_2 = 0$)	:	-2.84

No significant departure from the assumptions was found except for the small R^2 value. However, subsequent efforts to find additional explanatory variables were fruitless. Even the Vietnam indicator variable proved insignificant. Even though the sample size was reduced, the D statistic falls in the region implying no autocorrelation (for n = 15). The F statistic permits rejecting the hypothesis that $\underline{\beta} = \underline{0}$ at the one percent significance level. The t statistics both indicate significance, however, at the five percent level. To interpret the coefficient of x_2 we again use the dilution argument. That is, there has been a long term decrease in the number of navigators per USAF aircraft which will probably continue (contingent on the number of B-1's bought). Interpretation of the coefficient of x_1 is clear.

<u>Navigators Attending AFIT</u>. With this model, we turn to the categories of navigators not actively flying. As with the pilot categories, the basic hypothesis of this thesis cannot be tested and other

explanatory variables must be found. The model found for pilots attending AFIT did not prove significant for navigators. The model that did follows.

Table XXV

Model for Navigators Attending AFIT

Equation	:	$y = -236 + 0.06\ x_1$
Variables	:	y - navigators attending AFIT
	:	x_1 - total USAF aircraft
Means	:	$\bar{x}_1 = 10{,}992$
Sample Size	:	n = 11
R^2 coefficient	:	0.93
Durbin-Watson Statistic	:	D = 1.17
F Statistic ($\underline{\beta} = \underline{0}$)	:	52.4
t Statistic ($\overline{\beta}_1 = \overline{0}$)	:	10.9

The model displayed no evidence of significant departure from basic assumptions. The D statistic, however, falls in the inconclusive region and so we must turn to the Runs test for an indication of autocorrelation. For this model, the test statistic was R = 4 which implies that one cannot reject the hypothesis of randomness. Hence there is no strong evidence of autocorrelation. Both F and t statistics are sufficient for one percent significance.

During the search process, another independent variable was found by itself, to be highly significant alone ($R^2 = .91$): total USAF officers. The significance of these two separate models suggests that some underlying variable "explains" the variation in navigators attending AFIT. The interpretation preferred here is that both independent variables represent an aggregate measure of relative USAF prosperity.

This model then says that with increasing prosperity, more navigators are permitted to attend AFIT.

Undergraduate Navigator Trainees. The final model selected in this category involved a lengthy search process. The result is not as intuitively appealing as for the UPT model. In fact, the UPT model was not significant when applied to the UNT category. None of the variables which seek to measure deficiencies in the active flying force proved significant. The Vietnam indicator variable was also insignificant. The best result that could be found is presented below.

Table XXVI

Model for Undergraduate Navigator Trainees

Equation	:	$y = -1828 + 59\ x_1 - 0.39\ x_2 - 680\ x_3$
Variables	:	y - undergraduate navigator trainees
	:	x_1- total USAF officers (thousands)
	:	x_2- total USAF aircraft
	:	x_3- fraction of the F-4 force with navigators
Means	:	$\bar{x}_1 = 114.9$
	:	$\bar{x}_2 = 10,405$
	:	$\bar{x}_3 = 0.923$
Sample Size	:	n = 13
R^2 coefficient	:	0.63
Durbin-Watson Statistic	:	D = 1.12
F Statistic ($\underline{\beta} = \underline{0}$)	:	7.69
t Statistic ($\beta_1 = 0$)	:	3.78
($\beta_2 = 0$)	:	-3.90
($\beta_3 = 0$)	:	-2.77

There was no evidence of assumption violation except the normality assumption. Recall that the initial test used for normality is a probability plot of standardized residuals which should be linear. The plot for this model was such that further investigation seemed warranted.

Therefore, a Chi-square goodness-of-fit test for normality of the residuals was performed (Mendenhall and Schaeffer 1973). Using six cells divided at -2σ, $-\sigma$, 0, $+\sigma$, $+2\sigma$, the test indicated that one could not reject the hypothesis of normal residuals. Because of this test and the approximate linearity of the probability plot, then the assumption of normality was considered satisfied.

The D statistic falls in the region where that test is inconclusive. Therefore a runs test was performed the result of which was an inability to reject the hypothesis of randomness of the residuals. Absence of autocorrelation was concluded.

All F and t statistics indicated significance at the one percent level except for β_3 which was significant at the five percent level.

Interpretation of the sign of the coefficient of x_1 is straightforward. An increase in total USAF officers was accompanied by an increase in UNT's. Note that the size of the coefficient implies a shift of distribution of the officer corps. For the coefficient of x_2 we use the dilution argument again. Greater numbers of USAF aircraft imply a decreasing fraction of the aircraft needing navigators which implies decreasing need for UNT's. The coefficient of x_3 is of proper sign (intuitively). As more navigators became trained in F-4 aircraft, the need for training new ones (UNT's) diminished.

<u>Navigators Attending PME Schools</u>. For this model, the comparable model for pilots proved most significant except that certain variables were insignificant. So the argument used for pilots attending PME school applies here. The model is presented in Table XXVII.

Table XXVII

Model for Navigators Attending PME Schools

Equation	:	$y = -869 + 815\ x_1$
Variables	:	y - navigators attending PME schools
	:	x_1- ratio of total navigators to total aircraft
Means	:	$\bar{x}_1 = 1.54$
Sample Size	:	n = 12
R^2 coefficient	:	0.59
Durbin-Watson Statistic	:	D = 0.696
F Statistic ($\underline{\beta} = \underline{0}$)	:	6.81
t Statistic ($\beta_1 = 0$)	:	3.59

There was no evidence of significant departure from the basic assumption. The D statistic falls in the uncertain region and therefore a runs test was performed. This test would not permit rejecting the hypothesis of randomness and so no autocorrelation was concluded. Both F and t statistics indicate one percent significance.

The coefficient of x_1 is interpreted just as for the comparable pilot model. That is, there exists some threshold for this ratio above which the opportunity for navigators to attend PME schools increased. Since the estimated coefficient is so large, we conclude that the ratio was above the threshold during the time period covered.

None of the other variables examined were significant. These included the Vietnam indicator variable, U.S. gross national product, total USAF officers, and the like. The conclusion of interest here, though, is that the Vietnam conflict had no significant effect on navigators attending PME schools (as contrasted with pilots attending PME schools).

Supplement Navigators. For this final model, the comparable pilot model fit best. So again, the theory advanced for pilots in the supplement applies to navigators in the supplement. That is, deficiencies in the actively flying navigator force lead to demand for navigators in the supplement to return to flying jobs. The model follows.

Table XXVIII

Supplement Navigator Model

Equation	: $y = 15888 - 293\,x_1 + 2586\,x_2$
Variables	: y - Supplement navigators
	: x_1 - Vietnam indicator variable
	: x_2 - Percent of the navigators actively flying
Means	: $\bar{x}_1 = 0.727$
	: $\bar{x}_2 = 25.8$
Sample Size	: $n = 11$
R^2 coefficient	: 0.72
Durbin-Watson Statistic	: D = .55
F Statistic ($\underline{\beta} = \underline{0}$)	: 14.6
t Statistic ($\beta_1 = 0$)	: -3.64
($\beta_2 = 0$)	: 3.82

Again there was no evidence of significant departure from any assumptions. The D statistic falls in a region suggesting either positive autocorrelation or uncertainty about the test. The subsequent runs test would not permit rejection of the randomness hypothesis. No autocorrelation was concluded. Finally, all F and t statistics implied one percent significance.

The conclusion about the navigator supplement is the same as for the pilot supplement (contrary to the theory). The more actively flying navigators there are, the larger the navigator supplement. However, for

this model, the Vietnam conflict had a significant effect. Existence of the conflict required a decrease of 293 supplement navigators.

Chapter Summary: Some Overall Inferences

The thesis objective addressed by this chapter is development of a suitable set of models, one for each category of pilots and navigators, employing the assumptions and the theory of the Standard Linear Model. Throughout the development, an underlying hypothesis guided the search for appropriate variables; namely, that the number of rated officers in some category was primarily a function of the number of aircraft in that same category. Departures from this theme were made only when some category of aircraft obviously did not relate to a particular category of rated officers (e.g. pilots attending AFIT). In this section, we will view this rather large collection of models in the aggregate and draw some overall inferences regarding the aptness of the approach used. In addition, several other points which result from this analysis can and will be made.

The Basic Hypothesis. There was substantial evidence to support the basic hypothesis described above. In fact, in virtually every model where aircraft in some category was an appropriate independent variable, the model selected ratained this variable. From this we conclude that the manpower planning process does take aircraft into account when deciding where rated officers are to be assigned.

Aptness of the Standard Linear Model. This question has to do with the extent to which the assumptions of the Standard Linear Model (including normality) are satisfied for each of the models examined. In this analysis, of the 20 models developed, problems involving violation

of assumptions were experienced on but six of these of which four involved smaller R^2 values. With that sort of result, in the aggregate, we conclude that the use of the Standard Linear Model is apt.

Autocorrelation. Among the problems expected with time series analyses is that of autocorrelation. For the regressions developed here, there was a surprising lack of autocorrelation. Indeed, in every test for autocorrelation, one could not conclude with confidence that it existed. Admittedly the Runs test used for some models has low power. But the general observation is a lack of autocorrelation of residuals.

Effects of Vietnam. In general, the Vietnam conflict (as measured by the indicator variable) had an effect on the numbers of rated officers in the various categories. However, it did not prove significant in as many of the categories as expected (the variable was significant in nine of the 20 examined or 45 percent). Nevertheless, there was sufficient evidence of the effects of Vietnam to permit analysis of the changes in distribution of the rated force that this conflict brought about. This topic will be addressed in Chapter IV.

General Observations. The categories of rated officers used, although aggregated, can be grouped into still broader categories. If one groups the models into the two categories of pilots and navigators, respectively, he can observe that the models for pilots are generally "better" in an overall sense than the models for navigators. This phenomenon was particularly evident in the bomber category. The appropriate model for bomber navigators required lagging the independent variable of interest (bomber aircraft) by one year. The not-so-subtle suggestion of this result is that manpower planners also lag in their planning for bomber navigators.

Another useful observation is that models of rated officers (both pilots and navigators) in nonflying categories were generally weaker than those related directly to aircraft. This result suggests that once a rated officer leaves the actively flying force, it is more difficult to predict his future assignments. In the aggregate, this means that the management of rated officers in nonflying jobs is a problem involving more variables of importance than for those rated officers actively flying.

IV. FORECASTS OF DISTRIBUTION

In this chapter, use will be made of the models developed in the preceding chapter to forecast future distributions of the rated officer force. In Chapter III, the number of pilots or navigators in each category was made a function (usually linear) of one or more independent variables. That is, we have transformed one set of variables into a different (larger) set through these models. Thus, in order to forecast future distribution using these models, we must first forecast the set of independent variables into the future. In the table that follows, a collection of these variables from all the individual models is presented.

Table XXIX

Independent Variables to be Forecast

Aircraft Variables	Manpower Variables
Number of bombers	Total pilots
Number of tankers	Total navigators
Number of Fighter/Attack Aircraft	Actively flying pilots
Number of Reconnaissance Aircraft	Actively flying navigators
Number of Strategic Airlift Aircraft	Total USAF officers
Number of Tactical Airlift Aircraft	Financial Variables
Number of Other Aircraft	Total USAF outlays
Total USAF Aircraft	

In order to forecast these variables, a variety of sources was consulted. These sources differed depending on what future fiscal year was involved.

In addition, all the data on aircraft and budgets for FY 1978 and beyond are regarded as classified information. Therefore, the only years forecasted in this chapter are FY 1976 and FY 1977. Analysis of the remaining years may be found in Appendix B which is under a separate cover (classified SECRET).

The data for FY 1976 and FY 1977 were found largely from previously used sources. All the aircraft data and financial data were merely extensions of tables previously used (HQ USAF 1976). Forecasts of total USAF officers were also found there. Data for total pilots and navigators are routinely forecast for planning purposes by manpower planners (Military Personnel Center 1976). Finally, data for actively flying pilots and navigators was available from the remainder of the whole data set (the sum of the rated officers in those categories associated with active flying). Admittedly this procedure is incestuous but the resultant totals were not out of line with prior years' data. In addition, no other source was available (other than attempting an independent projection, which would have been rather close to the data used). The total data set for FY 1976 and FY 1977 is given in Table XXX. Note that in this table (and the ones in Appendix B), data were not presented for the transition quarter between FY 1976 and FY 1977. Those data were not used (even though available) because of the independence problem (see Chapter III). So the length of FY 1977 was, in effect, assumed to be 15 months. The effect of this assumption was considered minimal on those models with lagged variables; for the other models, it probably reduces any dependence that may have existed.

Table XXX

Complete Data Set

	FY 76	FY 77
Numbers of Aircraft		
Bombers	422	420
Tankers	621	585
Fighter/Attack	2495	2552
Reconnaissance	411	398
Strategic Airlift	349	347
Tactical Airlift	535	529
Other	482	494
TOTALS	7123	7121
Numbers of Personnel		
Total pilots	28396	25942
Total navigators	12871	12194
Actively Flying Pilots	6100	6007
Actively Flying Navigators	4051	3808
Total USAF Officers	99500	96100
Total USAF Outlay ($ billions)	26.2	28.2

Approach to Prediction Intervals

The normality assumption of the Standard Linear Model offers an opportunity for probabilistic statements about the projections made in each category (Mendenhall and Schaeffer 1973). In particular, the prediction interval about any prediction, $\hat{y}$, is given by $\hat{y} \pm t(\alpha/2)\, s\sqrt{1 + \underline{a}'(x'x)^{-1}\underline{a}}$ where X is the matrix of (past) observations, $\underline{a}$ is a vector of predicted values of the independent variables, s is an estimate of the standard deviation of the prediction, and $t(\alpha/2)$ is the value in the Student's t distribution for which the probability of falling within the interval is

(1 -α). In the next section, these prediction intervals will be given for each prediction made.

Since the prediction errors in each individual category are normally distributed (by assumption) then if we are willing to assume independence, we may use these errors to develop a prediction interval about the <u>sum</u> of the pilots or navigators in each category. Noting that the sum of independent, normally distributed random variables with means μ_i and variance $\sigma_i{}^2$ is normal with mean $\Sigma\ \mu_i$ and variance $\Sigma\ \sigma^2$, the extension of the previous prediction interval theory to the sum is straightforward. For the case at hand, the (1 -α) prediction interval for the sum of $\hat{y}_i$, $i = 1, 2, \ldots .m$ is estimated by

$$\sum_{i=2}^{m} y_i \pm t(\alpha/2) \sqrt{\sum_{i=2}^{m} s_i^2 \left[1 + \underline{a_i}' (x_i' x_i)^{-1} \underline{a_i} \right]}$$

where m is the number of individual predictions made for each category and those variables with subscripts correspond to ones used in the individual regressions.

Two additional assumptions must be made in order to use this formula. The first has to do with the way in which the t statistic was developed in the thoery. We obtained a statistic which was t distributed with r degrees of freedom by dividing a standard normal random variable by the square root of a Chi Square random variable divided by its degrees of freedom, r (Theil 1971). The extension to the sum is acceptable <u>except</u> that the term in the denominator is now the sum of Chi square random variables each with different degrees of freedom. This sum of Chi square variables is no longer Chi square distributed. A procedure exists for dealing with this problem. Basically, we define a new variable which has the same first moment as a Chi square variable divided by its degrees of freedom and then estimate the degrees of freedom necessary to

match the second moments of the Chi square and the new variables (Dei Rossi 1968). The resulting expression was evaluated for several of our distributions of rated officers. Estimated degrees of freedom for these cases ranged from 25 to 30. Since a t distribution with 30 or greater degrees of freedom is essentially normal, we conclude that the distribution of the sum is nearly normal. We are assuming, in effect, that the sum is <u>normally</u> distributed with mean $\sum_{i=1}^{m} \hat{y}_i$ and variance $\sum_{i=1}^{m} \hat{\sigma}_i^2$ where $\hat{\sigma}_i^2$ is the estimate of the variance in the ith regression.

The second assumption needed is that of statistical independence among the dependent variables. In context, this means, for example, that the number of (future) bomber pilots is independent from the number of tanker (or airlift, or fighter/attack) pilots.

Recalling that we have an independent estimate of these sums as part of the original data set, a comparison can be made between this value and the prediction interval developed above. If the independent estimate falls outside of the $(1 - \alpha)$ prediction interval, then we say that a significant change (in policy) is to occur.

In the sections which follow, the results of this approach are presented. These are grouped by fiscal year for pilots and navigators separately.

Results for Fiscal Year 1976

Although this year is already past, for our purposes, it is not. There is a time lag in developing data which makes it unavailable until some time after the end of the period being summarized. Therefore, FY 1976 data is not yet available and our analysis is indeed a prediction. Figure 1 contains the predicted distribution for pilots in each of the categories. What is plotted is the 90 percent prediction interval with mark at each end and the mean.

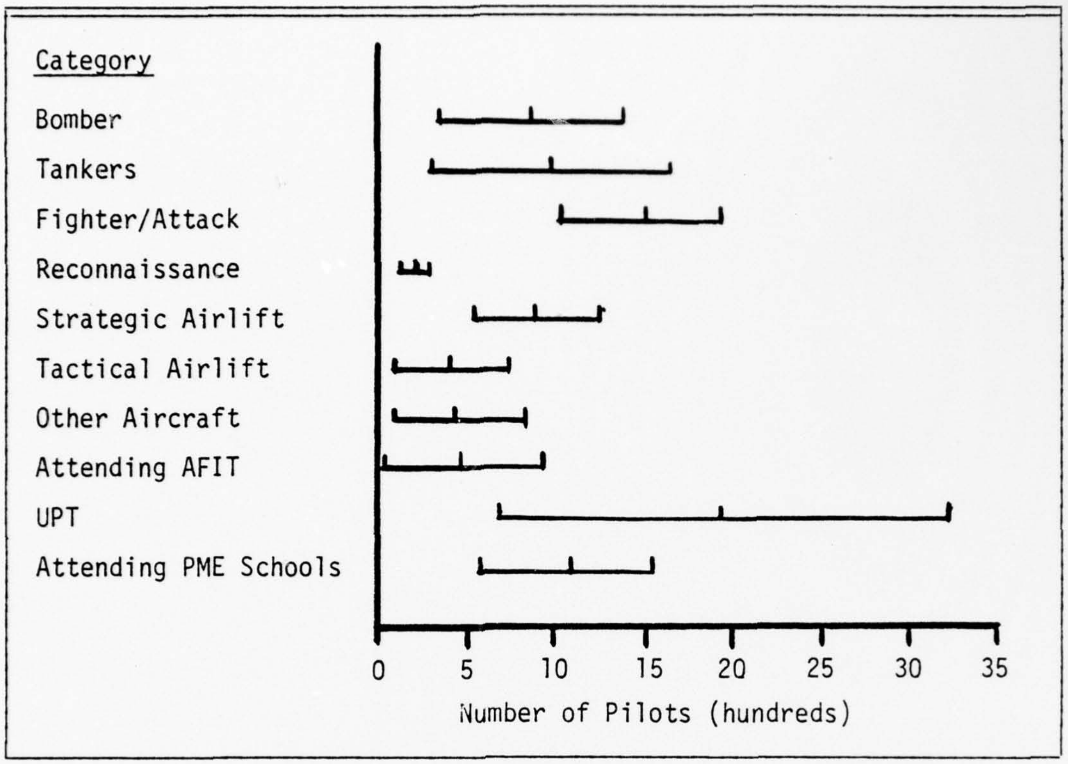

Figure 1. Predicted Distribution of Pilots for FY 1976

Because of their relative magnitude, the Supplement category and Total pilots were omitted from the figure. The prediction for the Supplement resulted in a 90 percent prediction interval of (23776, 29126) and the interval for total pilots was (32263, 38061).

Two observations are immediately apparent from the prediction. First, the individual prediction intervals are rather large even though the corresponding regressions "explained" large amounts of variance. The conclusion is that even though we observe large R^2 values, substantial intervals still result. In our context, this means that the system we are modeling has inherently large variance. In short, we cannot predict with reasonable accuracy the number of pilots in any particular category.

Second, the 90 percent prediction interval for total pilots, although relatively small (within 10 percent of the mean), does not cover the independent projection of that data point. This suggests that some significant policy change has occurred which will reduce the size of the total pilot inventory. Since the largest portion of the inventory is in the Supplement, the change most likely involves this category.

The comparable data for navigators is presented in Figure 2. The format is the same as for pilots except that airlift aircraft were aggregated.

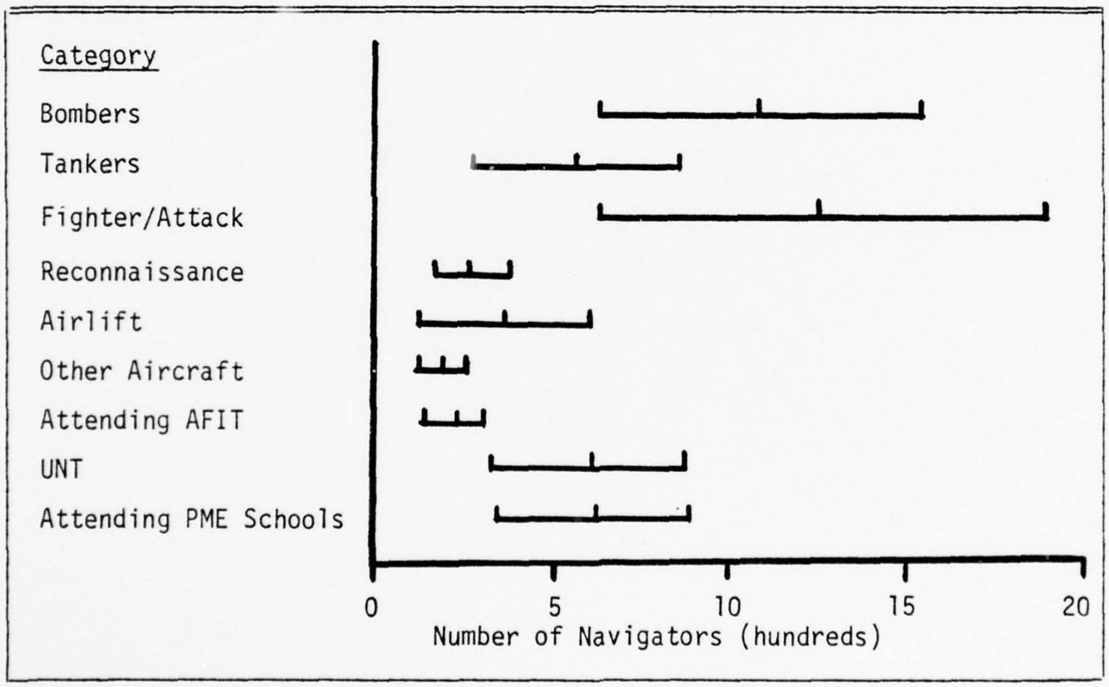

Figure 2. Predicted Distribution of Navigators for FY 1976

Again the supplement category and total navigators were omitted because of their relative size. Their respective 90 percent prediction intervals are (4330, 8988) and (9310, 13842).

The observations to be made for navigators differ somewhat than for pilots. First, we observe the same large interval phenomenon as before. (The reader should note the scale change, which makes variance appear larger than it is.) Second, and more significant, the independent estimate of total navigators falls within the 90 percent prediction interval for total navigators. This is partly because the interval itself is relatively larger (now within 20 percent of the total vice 10 percent for pilots), but the estimate is rather close to the mean of 12090. We conclude that if a significant policy change has occurred, it will not influence the total navigator inventory even though this system also has large inherent variance.

Results for Fiscal Year 1977

Figures 3 and 4 present the comparable results for FY 1977 in the format of Figures 1 and 2, respectively. These are not substantially different from the FY 1976 results except for a trend toward increasing prediction interval sizes. This trend is evidenced by the totals, which were (32294, 38174) for pilots and (8882, 13372) for navigators, respectively.

Again we observe the policy change phenomenon for total pilots and not for total navigators. From this and the above observations, the conclusions for FY 1977 are largely unchanged from those for FY 1976.

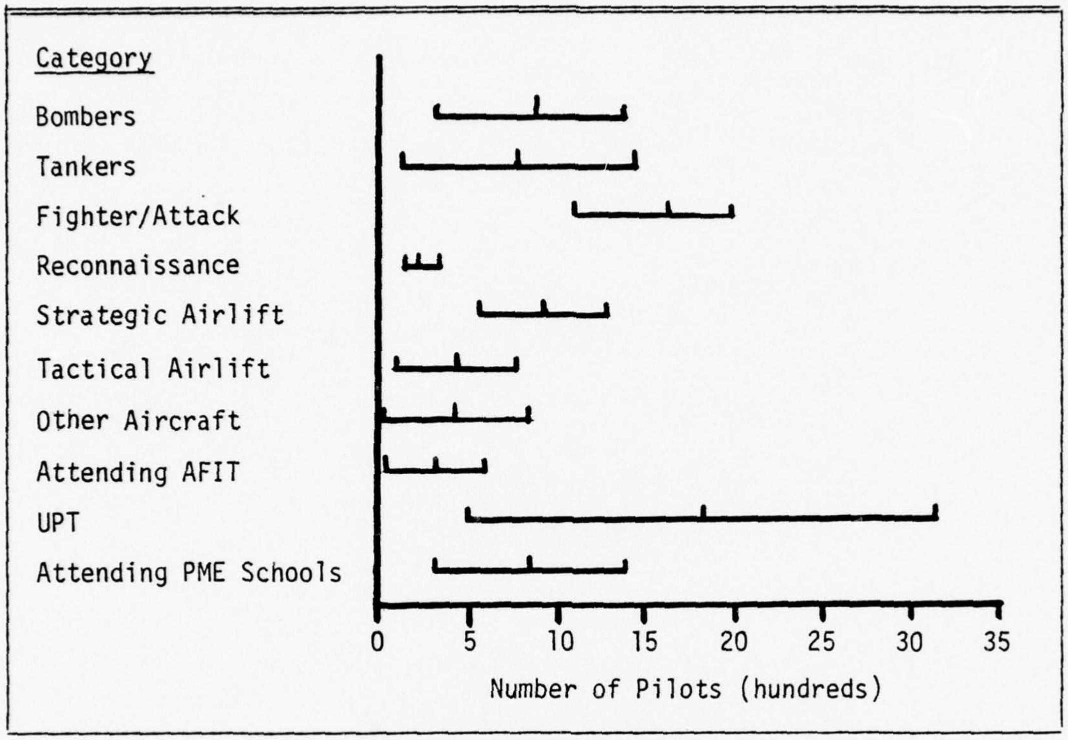

Figure 3. Predicted Distribution of Pilots for FY 1977

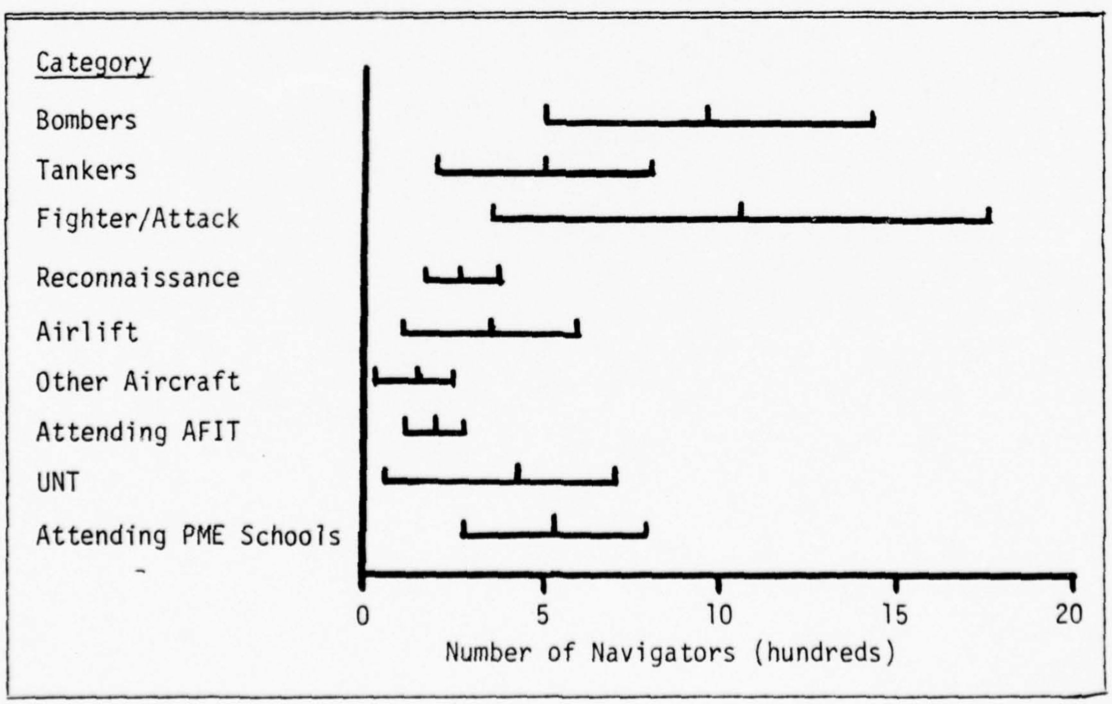

Figure 4. Predicted Distribution of Navigators for FY 1977

Chapter Summary

In this chapter we have examined predictions of distributions of pilot and navigator forces which were made by using the models developed in Chapter III. Distributions for both FY 1976 and FY 1977 were presented. Projections for the distributions in FY 1978 and beyond are contained in Appendix B and were moved there because of their security classification.

Two major observations can be made from the limited data for FY 1976 and FY 1977. The first is based on the proximity of independent estimates to the calculated totals of pilots and navigators. In both years, the independent estimates fell within the 90 percent prediction intervals for total navigators but not for total pilots. The conclusion drawn from this is that a significant policy change has occurred which will influence total pilots but not total navigators.

The second observation deals with intervals. Large intervals were noted for both the pilot and navigator categories. This condition was seen in large prediction intervals for every category of pilots and navigators examined. The conclusion drawn here is that the manpower system we are attempting to model has inherently large variance and that reasonably accurate prediction is difficult at best. In addition, a (short term) trend of increasing interval size with increasing time was noted. This trend existed even though the variable "time" was not explicitly included in any of the models used for prediction. We must conclude from this either that time alone does not influence our dependent variables (statistically) or that the time variable is embodied implicitly in the data set of independent variables.

V. IMPLICATIONS OF THE ANALYSIS: THE NEED FOR FURTHER RESEARCH

In the preceding chapters a method was described for forecasting the distribution of rated officers into the future on the basis of models developed using historical data. When taken as a whole, the analysis leads to some very important questions. If the USAF can expect to have some distribution at some future time, is that good or bad? What distribution is needed, for example, if the USAF Is to engage in combat operations in the NATO region? Is our planning process adequate to insure that rated manpower will not constrain these combat operations? It is, of course, in a wartime scenario that this adequacy will ultimately be tested.

These very difficult questions will not be "answered" in this chapter. However, the analysis in preceding chapters can shed some light on the questions posed and this in turn can point the way toward further needed research. This is the subject matter of this chapter. A discussion will be presented of potential conflicts and what demands for qualified rated officers they might create. The discussion will be in terms of the categories of pilots and navigators previously used. The implications of shortages in these categories in a wartime context will be described. Following this is a description of the planning process currently used to create future distributions of rated officers. This description is rather broad since an extensive discussion is well beyond the scope of this thesis. But even this limited knowledge of the current process leads to some suggestions regarding the reasons for the large interval and large Supplement phenomena noted in Chapter IV. The chapter concludes with a number of ideas for further research which are suggested by this analysis. The importance of the subject at hand fairly demands more effort.

Wartime Needs for Rated Officers

In what kinds of conflict must the USAF be prepared to be engaged? The answer, of course, is all kinds -- the spectrum of potential conflict. Nevertheless, there are two different types of conflict which seem most likely in the current context of world affairs: a quickly developing, short-term, nonnuclear war in which one of the major determinants of success will be employable force, and a protracted war of attrition similar to the Vietnam conflict. The demands placed on the rated officer force are quite different in these two cases. In the former, the needs are immediate and whatever qualified rated officers exist at the time will simply have to suffice. It is in this kind of scenario that deficiencies in some category of rated officers would have the greatest impact on the potential outcome of the conflict. The overwhelming influence of large numbers of sorties is well known. Therefore, if qualified pilots or navigators in some category are the constraining factor, this might well determine the outcome of the conflict. On the other hand, if the number of rated officers is not the binding constraint, then the rapid attrition expected in such a conflict would soon tend to make the existing stock of rated officers adequate to man the remaining aircraft.

In contrast in a protracted war (of attrition) the opportunity exists for the manpower system to react to increased demands for rated officers in some category. The Vietnam conflict provides a useful example of such a war. In this type of conflict the manpower planning problem becomes one of rotation policy. And if this policy is fixed, it is the speed of reaction and the capacity of the training base that become the factors which determine the adequacy of the existing distribution of rated officers. The analysis in the preceding chapters provides some

insight into the potential effects of another Vietnam type conflict. Table XXXI shows the changes in rated manpower created by the Vietnam conflict for those variables which proved significant in the regressions of Chapter III.

Table XXXI

Estimated Effect of the Vietnam Conflict on Rated Officer Distributions

Pilot Categories		Navigator Categories	
Tankers	+757	Tankers	+303
Strategic Airlift	+650	Fighter/Attack	+547
Tactical Airlift	+490	Airlift	+302
UPT's	+1575	Supplement	+2586
Attending PME Schools	-638		
NET CHANGE	+2834 (+6.1%)	NET CHANGE	+3738 (+19.9%)

These changes in the rated force represent the only ones that proved significant even though the Vietnam indicator variable was tested for all models. The result above indicates, (and with all other factors remaining the same) that the Vietnam conflict had a relatively small effect on the structure of the entire rated manpower force (additions of less than seven percent of the total force of pilots and 20 percent for navigators). What all of this indicates is that the then existing manpower base was sufficient to "cover" the needs for trained rated officers to support the conflict. This condition, of course, may not always be the case.

This discussion leads to our next consideration. What would be the effects of shortages in some category of rated officers? The key theme

here is that of interdependence. That is, shortages in one category will likely produce constraints on several other categories or mission areas. If there are not enough tanker pilots to fly the planned number of sorties, then all missions supported by tanker operations (notably fighter/attack sorties) will be constrained by the shortage of tanker pilots. Similarly, if the shortage is in fighter/attack pilots then the resulting constraint on fighter/attack sorties can increase the vulnerability of all other aircraft operating in the combat theater. Shortages in reconnaissance sorties brought about by too few pilots or navigators in this category could result in less relevant intelligence information for commanders to consider when making their decisions. Operating in this more uncertain atmosphere could then produce less efficient allocations of forces with obvious detrimental effects. Finally, shortages in airlift pilots or navigators could indirectly affect combat operations through a reduction of supplies to combat forces. Thus, we see that there exists an interdependence among missions in a combat situation such that shortages in rated officers in any one category could well affect all other missions.

Current Manpower-Planning Process

It is the possibility of future conflict situations which dictates the need for qualified rated officers, indeed for the entire USAF. To be prepared to support potential combat operations adequately, the USAF must plan for future rated forces to support these contingencies. This section provides a broad perspective of the current process by which the USAF plans for future distributions of rated officers and relates some of the phenomena previously observed to conditions present in this process.

The current planning process within the USAF is an annual one. It results in a number of official publications all of which support the budget submission each year. Among these publications is the USAF War and Mobilization Plan (WMP) (HQ USAF 1976). This document (in six volumes) indicates the forces (mission and support) which are expected to be available in the future and the way in which the USAF plans to use them under several different contingency situations. The WMP is the only USAF-level plan of its kind and represents the integration of all the respective plans of the individual Commands.

The WMP does not contain any quantitative expression of the needs for rated officers (in any categories) created by the scenarios addressed. This is not to say that such an expression of rated officer "requirements" does not exist. Rather we conclude that an ommission of important information has occurred in a USAF-level publication of some consequence.

What document does contain such an expression of rated officer requirements? It is another annual publication of major importance to the USAF, the Program Objectives Memorandum (POM). The POM presents all of the future programs the USAF plans to undertake or sustain within the funds provided by the Department of Defense (DOD). The POM contains these requirements for rated officers separated into categories (not the same as ours) based on the possible contingencies which the entire DOD plans against. The major drawback of the POM for determining rated officer requirements for our purposes is that it is constrained by the budget. This implies that the requirements for rated officers stated therein are constrained by the budget. Consider the simple model for calculating pilots required to support all the aircraft of one type in the inventory. It is simply the product of the crew complement (pilots per aircraft).

crew ratio (crews per aircraft), and the number of aircraft in the inventory. The first term is usually taken as invariant. (If the number is 1.0, it is indeed invariant.) The last two terms are those which are subject to budget constraints. One can fit within a budget by decreasing aircraft or crew ratio (in effect pilots) or both. These "cuts" can conceivably be rather arbitrary when the budget pressure is severe. Thus, developing requirements for rated officers from the POM could be a not-so-representative expression of what is needed in combat.

This planning situation could be viewed as a partial "explanation" for some of the phenomena we have observed earlier. In an atmosphere of shrinking budgets (in terms of real spending power) the implicit objective seems to have been to buy as much manpower and as many forces that can be bought <u>within the budget</u>. When one considers this idea and the fact that the rated manpower system must be prepared to support a spectrum of conflict situations, there is little surprise that large intervals were found. The observation also tends to "explain" the existence of a relatively large Supplement for both pilots and navigators. Finally, to the extent that it exists, the models of Chapter III capture a tendency to overman the pilot force. This tendency could be viewed as insurance for manpwoer planners -- a hedge against the uncertainty of wartime rated manpower requirements.

<u>Suggestions for Further Research</u>

The analysis in Chapter III and IV and the discussion above provide many paths of further research. In this section some of the more obvious ideas will be discussed.

First, there is the matter of rated officer requirements. Some useful work could be done to try to express these requirements as implied by

some future force structure of aircraft. A logical starting point for this analysis would be the POM, but some attempt should be made to remove the budget constraint from the resulting requirements. If developed, these requirements could then be comapred to the forecasts developed herein. The comparison could lead to valuable insights regarding the type of retraining that might be necessary in such a future war.

Given that the existing and desired distributions are known, the retraining process to convert one into the other must still be examined. This is the second idea for further work. Even if all trainees required the same amount of time to become qualified, there is still the question of the capacity of the training base. In addition, the eventual output of the process is subject to several other constraints: training aircraft, instructors, and weather. This latter variable could render even this process a stochastic one.

The third and final idea relates to the nonrated (officer) force. This force also exists to support future potential conflicts even though indirectly. Hence changes in the distribution of these officers could influence the outcome of a potential conflict. An approach similar to the one used in this analysis could be applied to the nonrated officer force. The proposed analysis, however, would be much more difficult because neither the "categories" nor the explanatory variables are as clear as with rated officers. Nevertheless, the value of the results of such an analysis seem to warrant further research.

VI. SUMMARY

The rated officer force of pilots and navigators is and will continue to be one of the more important factors in Air Force planning. Therefore, the process by which future rated officer forces are created is a problem which demands much thought and effort. The multi-faceted nature of the manpower planning task makes informed decision making a very complex undertaking. Nevertheless, the importance of the rated officer force demands that the USAF make an attempt.

In this thesis, the manpower planning process has been viewed as stochastic. That is, the state of the system at any particular time is determined by current policy and the collective effects of decisions made by individual rated officers as they proceed through their careers. The primary problem addressed by the analysis was whether changes in the distributions of pilots and navigators could be represented by linear, statistical models using appropriate independent variables.

The approach taken made extensive use of the Standard Linear Model including the assumption of normally distributed error (Theil 1973). The rated force was divided into some 10 broad categories for both pilots and navigators. For each of these categories a model was developed which best represented the variations in the number of pilots or navigators in that category. For those categories in whcih aircraft were involved in the manning process (active line flying positions) a basic hypothesis was tested. The number of pilots or navigators in any category was viewed as a (usually linear) function of the number of aircraft in that same category. For those categories where aircraft were obviously not relevant (e.g., AFIT attendees) individual hypotheses with intuitive appeal were developed and tested.

Data for the analysis was developed from that available in the USAF Statistical Summary (HQ USAF 1976) as well as a series of aircraft-characteristics handbooks (Aernoautical Systems Division 1975). The number of rated officers in any particular aircraft-related category was then calculated as the product of the number of crews formed and the number of pilots (or navigators) per crew for each aircraft type in the category. A number of important assumptions were necessary in order to convert the raw data into a useable form. An attempt was made to hold these assumptions to a minimum.

Data for the nonaircraft related categories was gathered, by and large, from the organizations responsible for those categories. For example, data for undergraduate pilot and navigator trainees were obtained from the Air Training Command. Similarly, data for AFIT attendees were obtained from that organization (AFIT/DP 1976). A similar attempt was made in these categories to minimize the necessary assumptions.

The collection of data from all these sources comprised the data base used for subsequent analysis. Using this data base, models were developed for each of the categories of pilots and navigators. These models were then used to forecast distributions of the entire rated officer force into the future. Prediction intervals were developed about each of these forecasts and also about the totals for each fiscal year examined. Because of the security classification of data for fiscal years 1978 and beyond, the forecasts for these years are contained in a classified appendix under separate cover.

The results of the analysis provide some valuable insights into the manpower system that was examined. The observations apparent from the analysis are listed below:

1. Substantial evidence exists in support of the basic hypothesis of this thesis. It appears that the manpower planning process does take aircraft into account when deciding where rated officers are to be assigned.

2. Use of the Standard Linear Model as a basic approach appears apt. There was a surprising lack of evidence of problems usually associated with this Model.

3. The models developed for pilot categories were generally better in an overall sense than those for navigators. The planning process for navigators appears to lag that for pilots. This was particularly evident in the bomer and tanker categories.

4. Models for rated officers in nonflying categories were generally weaker than those for active flyers. The suggestion this creates is that the process controlling these officers is more complex.

5. Forecasts of total navigators fell closer to the independent projections contained in planning documents than the forecasts for total pilots. The conclusion reached was that there is a tendency to overman the pilot force which is captured by the models.

6. Large prediction intervals were observed in virtually every category in spite of the high statistical significance of the models. This condition is viewed as a manifestation of the uncertainty surrounding potential future needs for rated officers.

The analysis suggests several paths for additional research. Most of these involve estimates of the consequences of having some future distribution of rated officers. The training process by which existing distributions are converted to desired ones needs to be addressed. The importance of rated manpower in any potential conflict of the future demands this attention.

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Appendix A

Graphic Representations of the Regression Models

Appendix A

Graphic Representations of the Regression Models

This appendix supplements the information contained in Chapter III. It provides a graphic picture of each of the models developed in that chapter. What is plotted in each is the fitted regression line together with the individual data points used to generate that line. This form or presentation provides the viewer with a "feel" for the data which can't be obtained using other forms. For multiple regressions, means were substituted for all independent variables but the one plotted.

The figures that follow were plotted by computer and are in the order of presentation in Chapter III. Ordinates and abcissas are labled in scientific notation. When a number appears near any particular data point, it denotes that number of multiple, superimposed data points there. The reader is cautioned that the origin of each figure is not the point (0,0) but is chosen based on the range of the data. Similarly, the scales of ordinate and abcissa are calculated so as to cover the range of the data and fit within the space available.

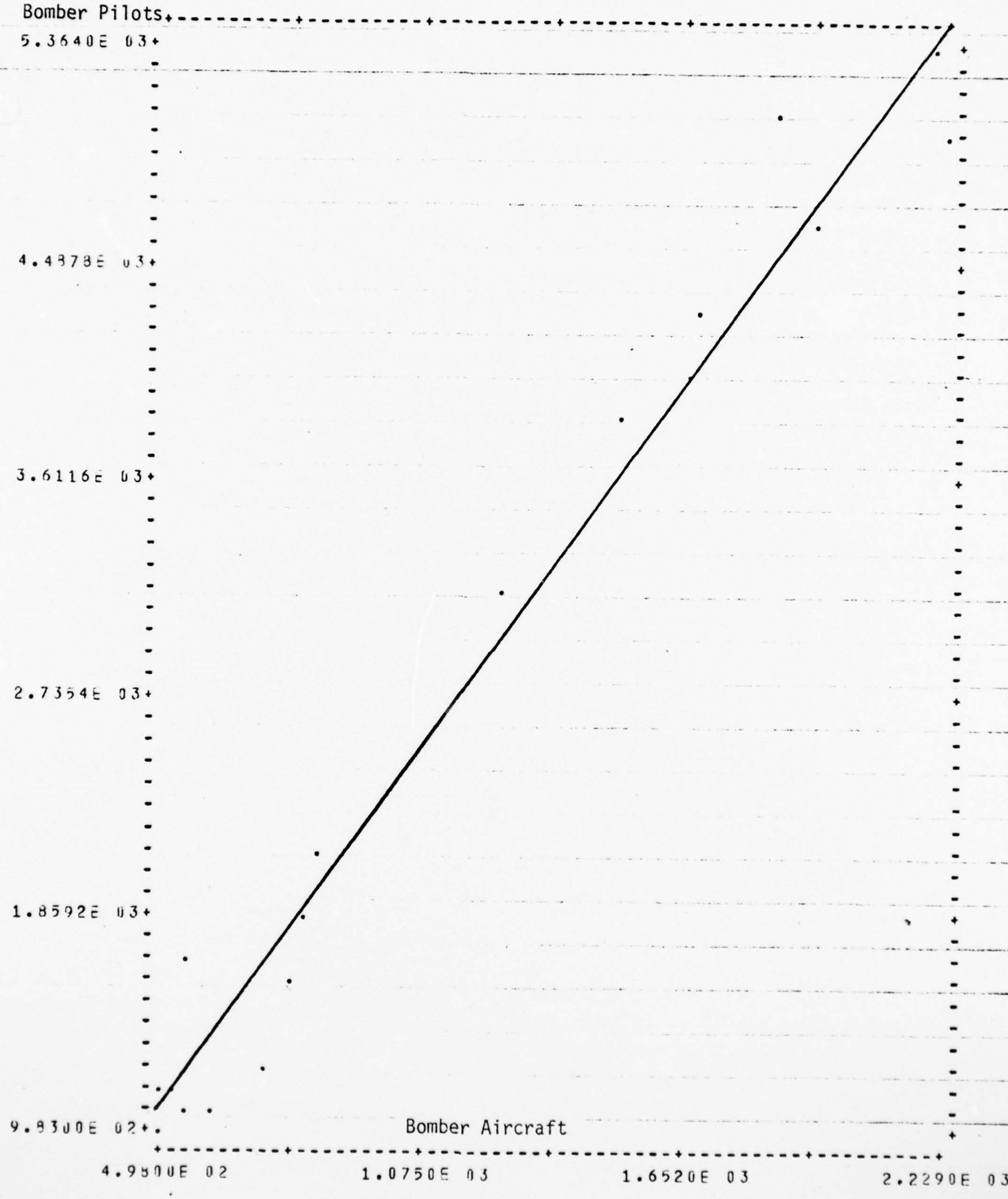

Figure 5. Bomber Pilot Graph

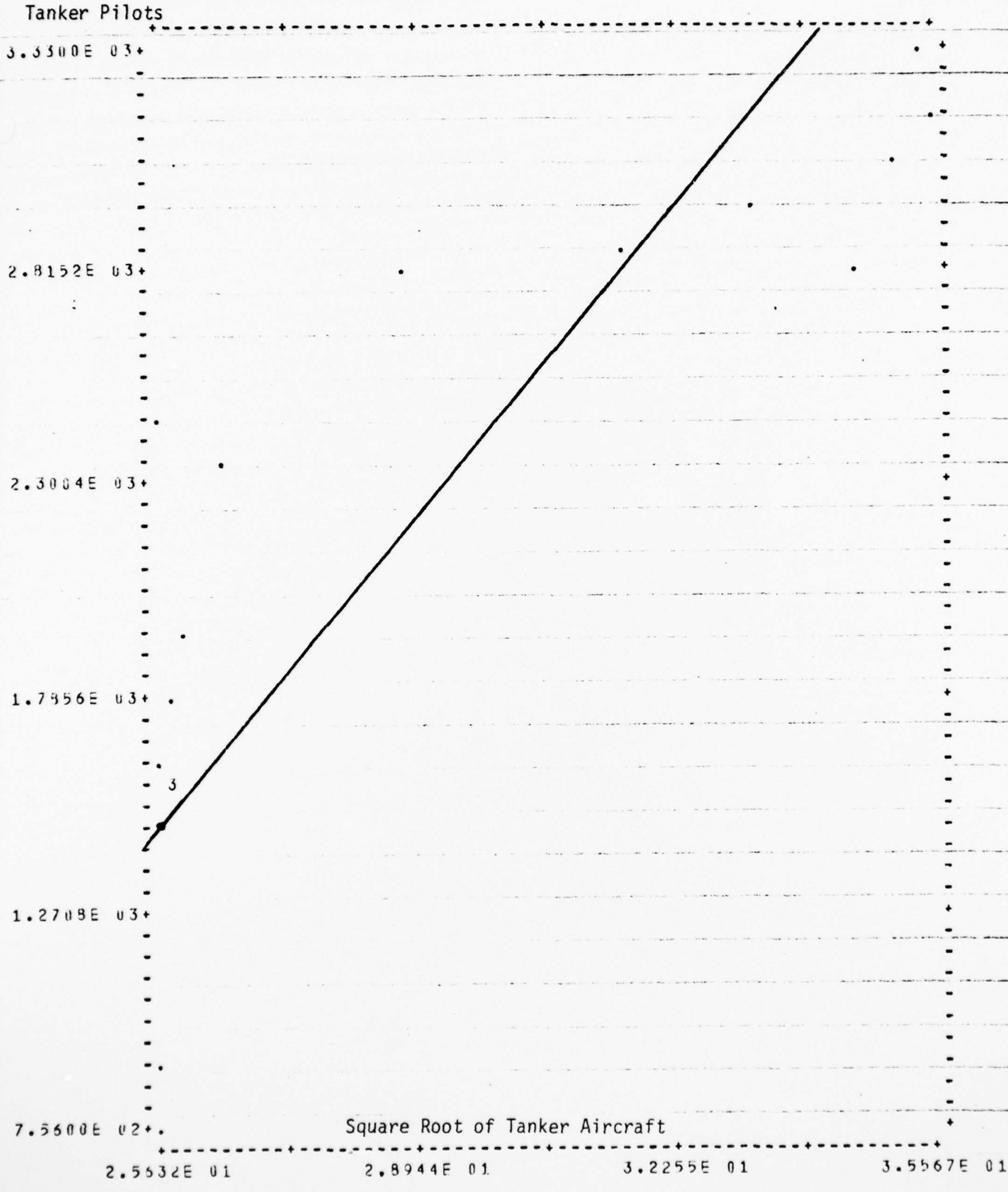

Figure 6. Tanker Pilot Graph

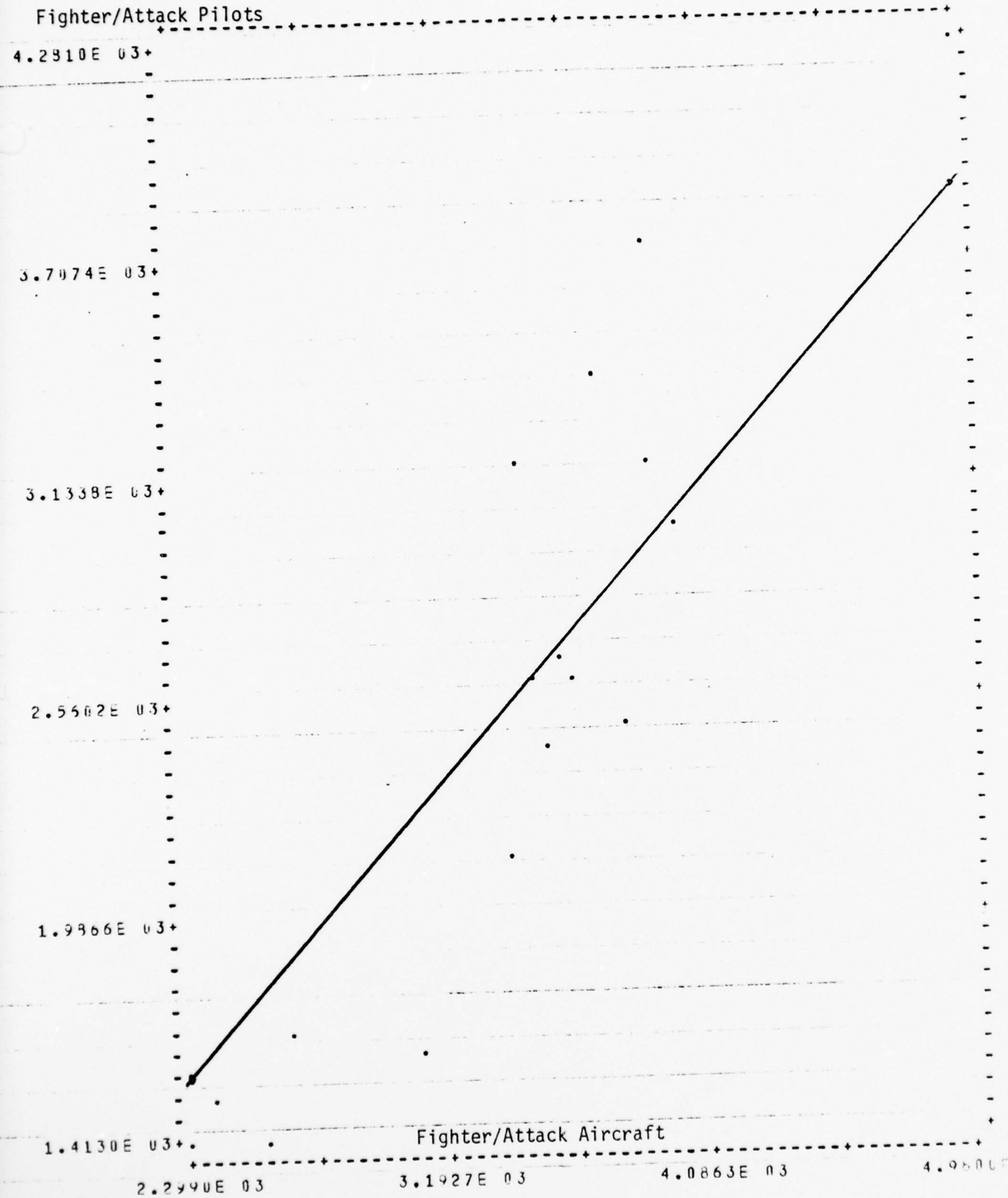

Figure 7. Fighter/Attack Pilot Graph

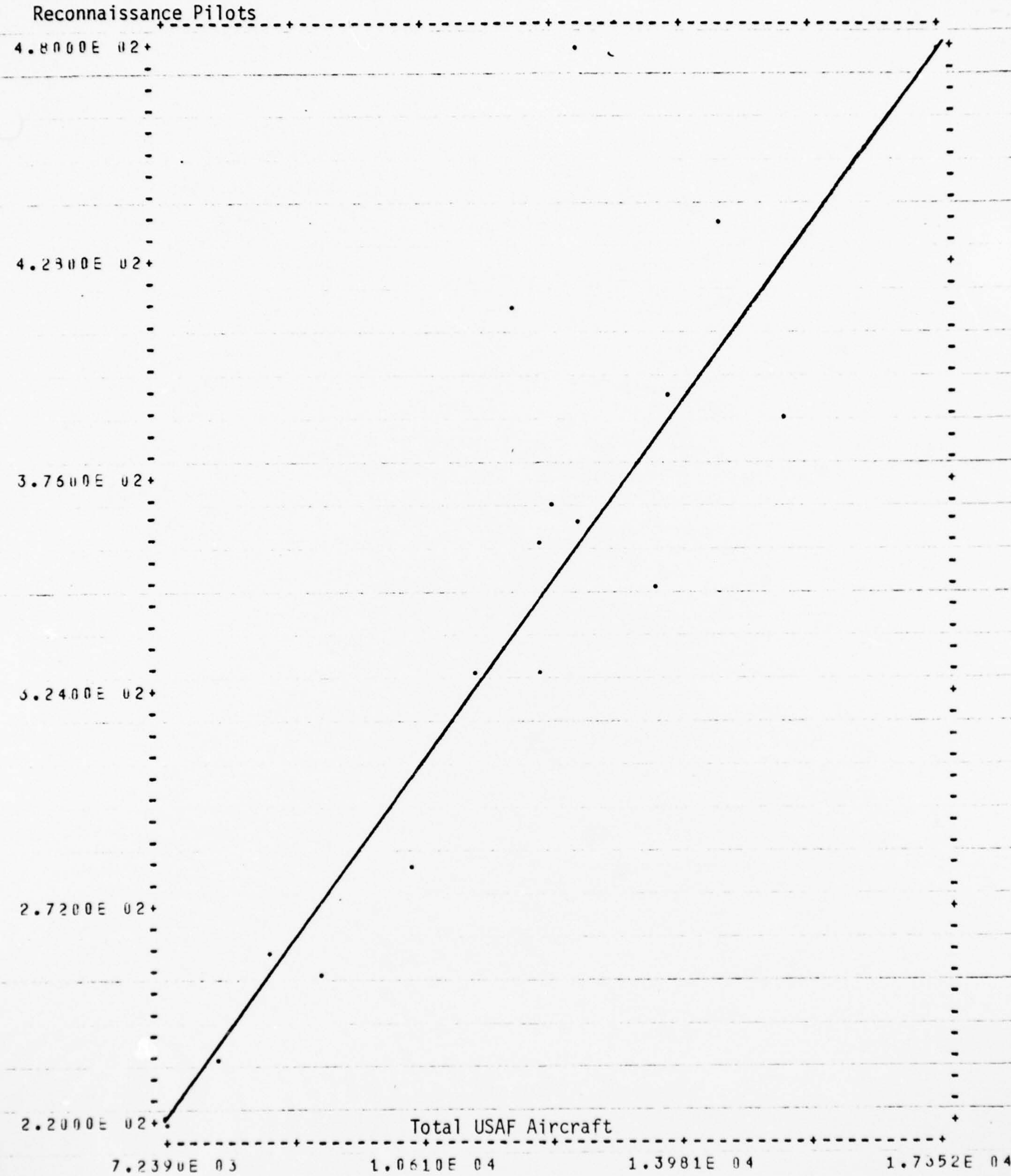

Figure 8. Reconnaissance Pilot Graph

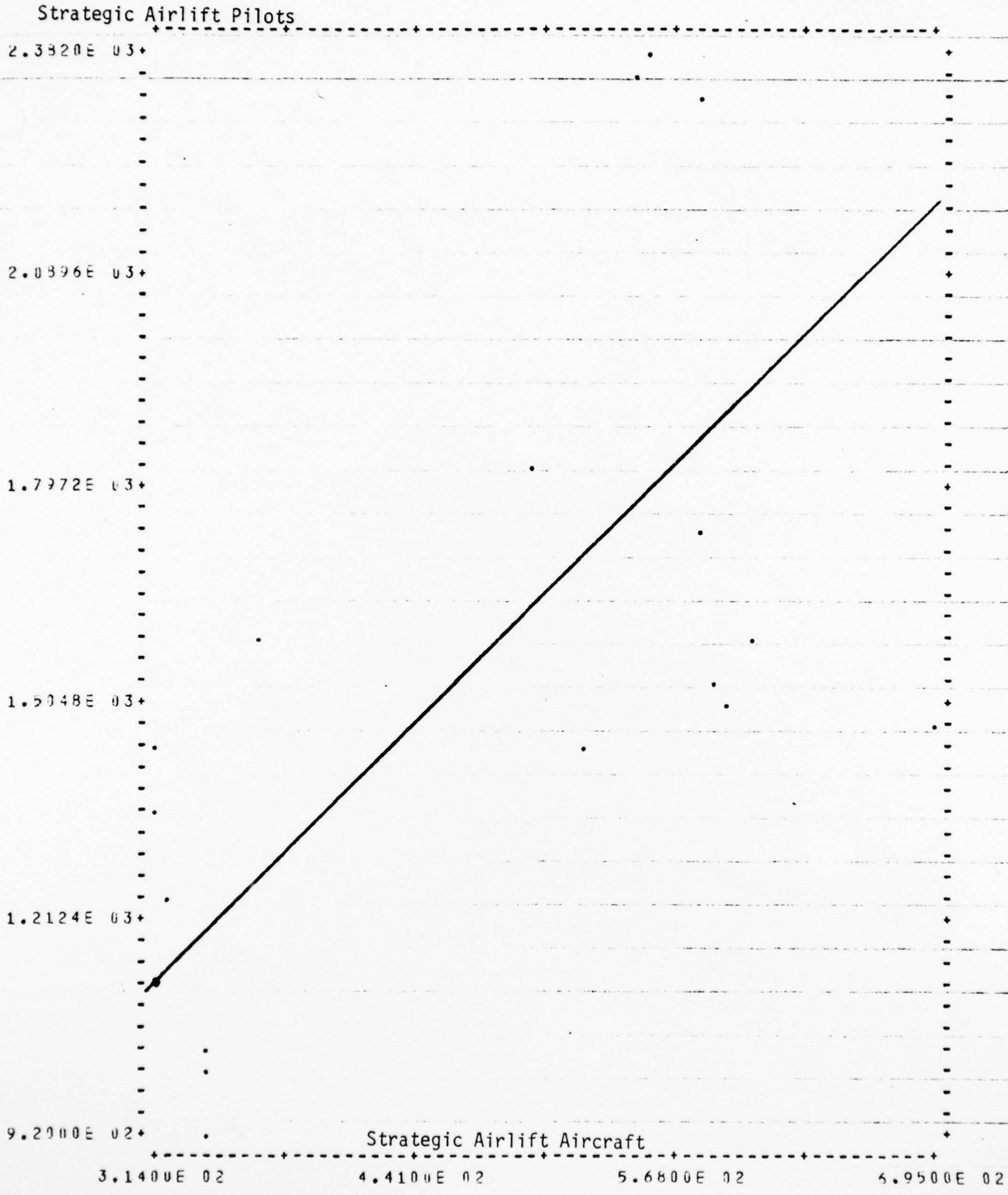

Figure 9. Strategic Airlift Pilot Graph

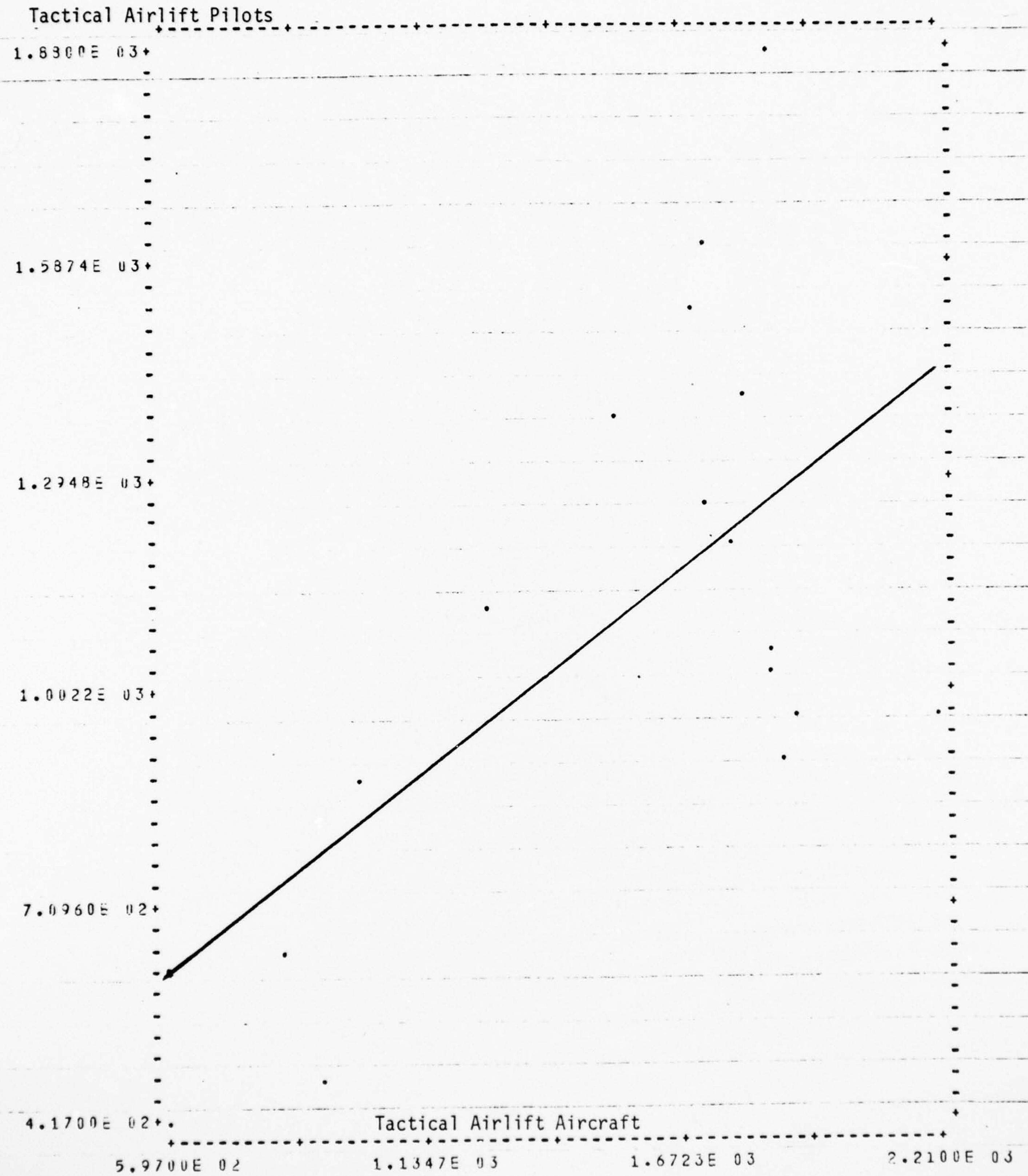

Figure 10. Tactical Airlift Pilot Graph

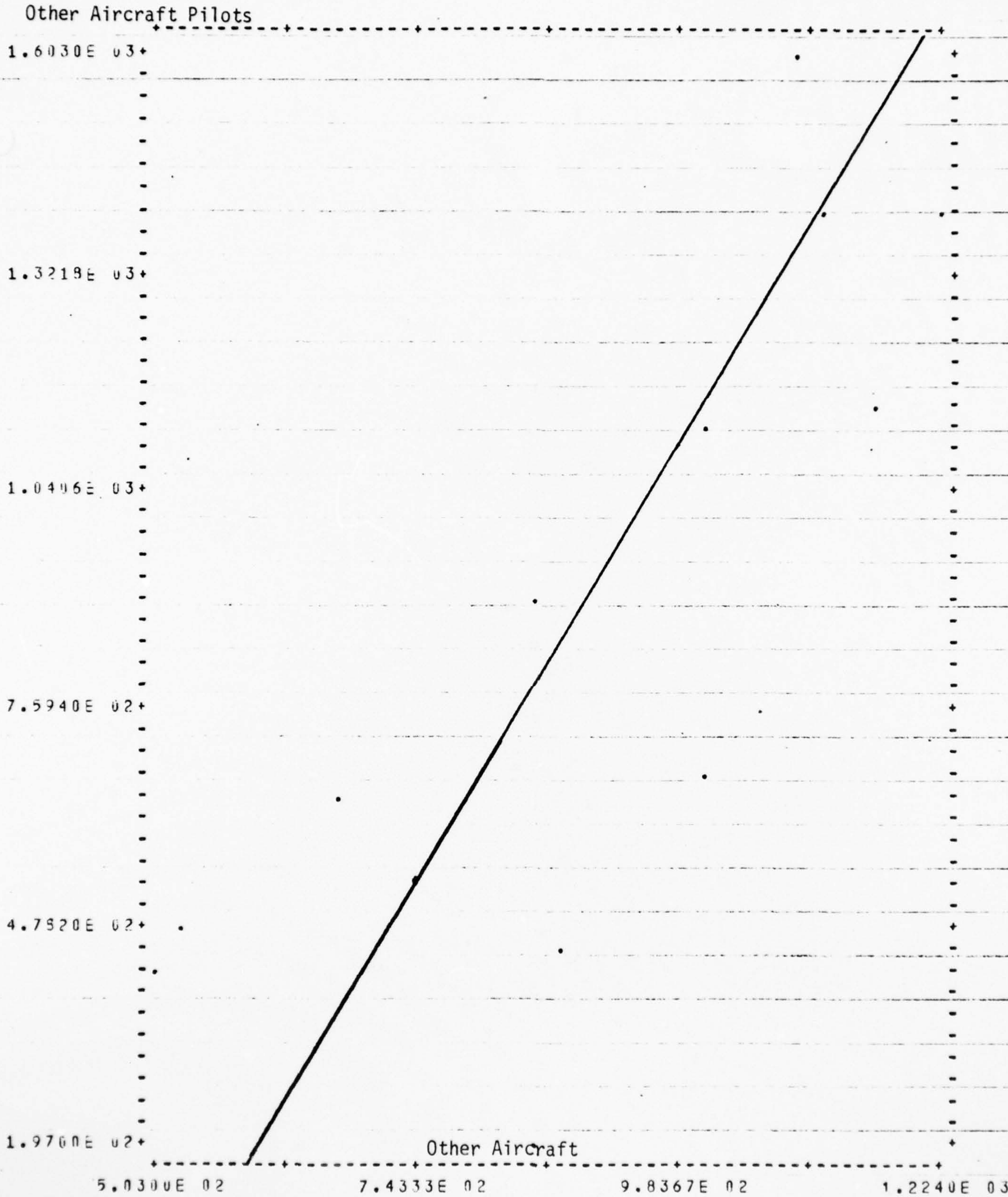

Figure 11. Other Aircraft Pilot Graph

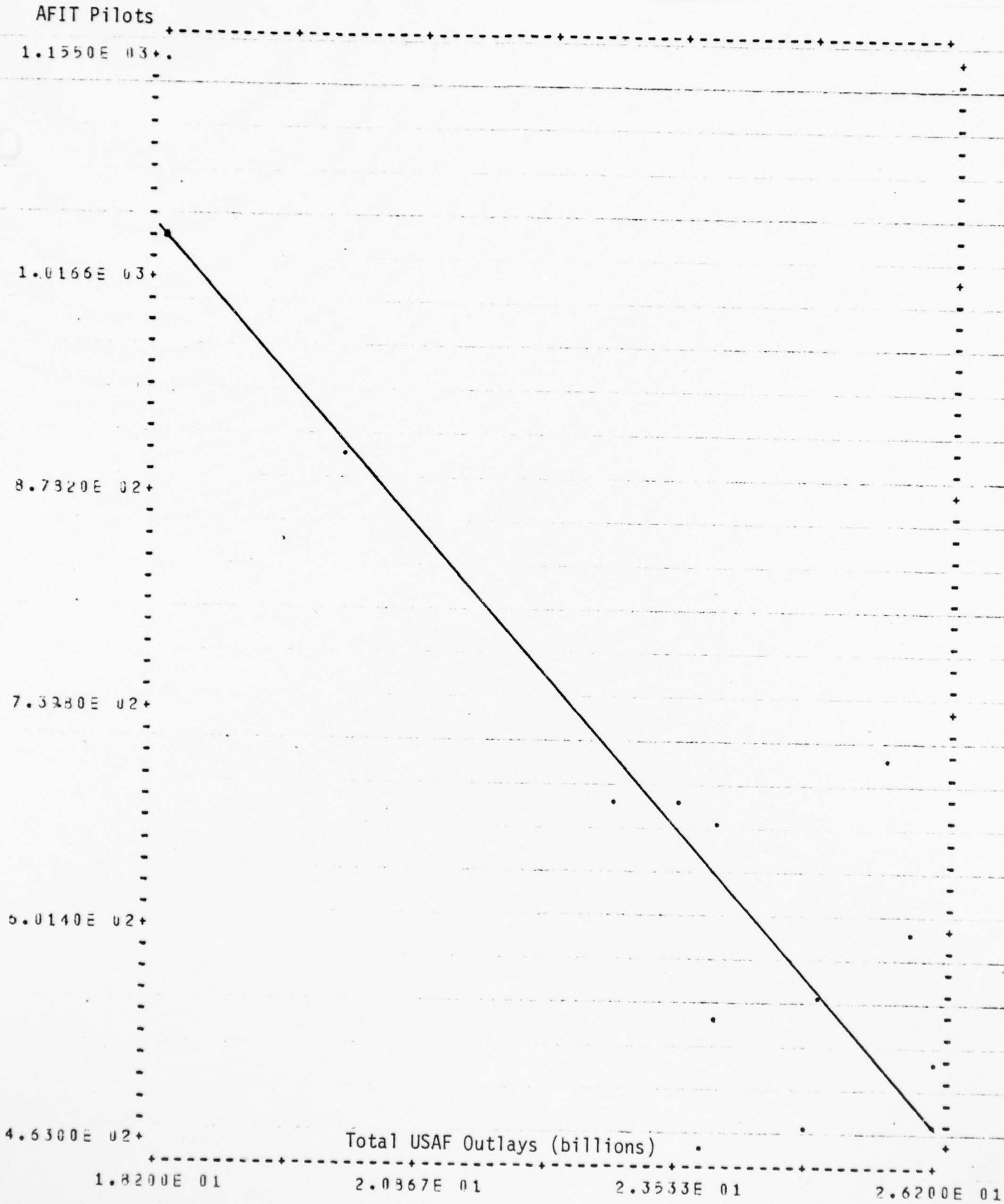

Figure 12. AFIT Pilot Graph

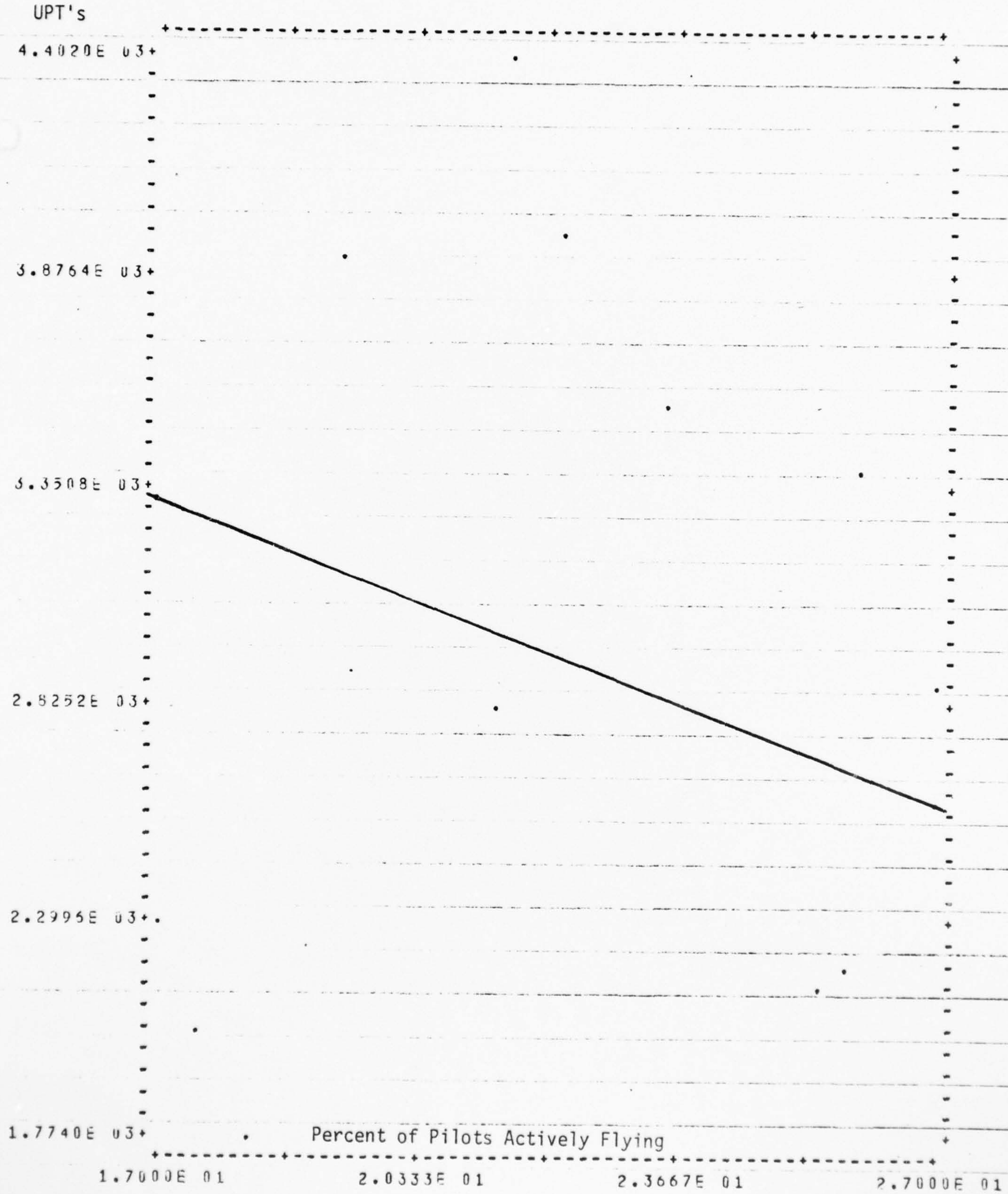

Figure 13. UPT Graph

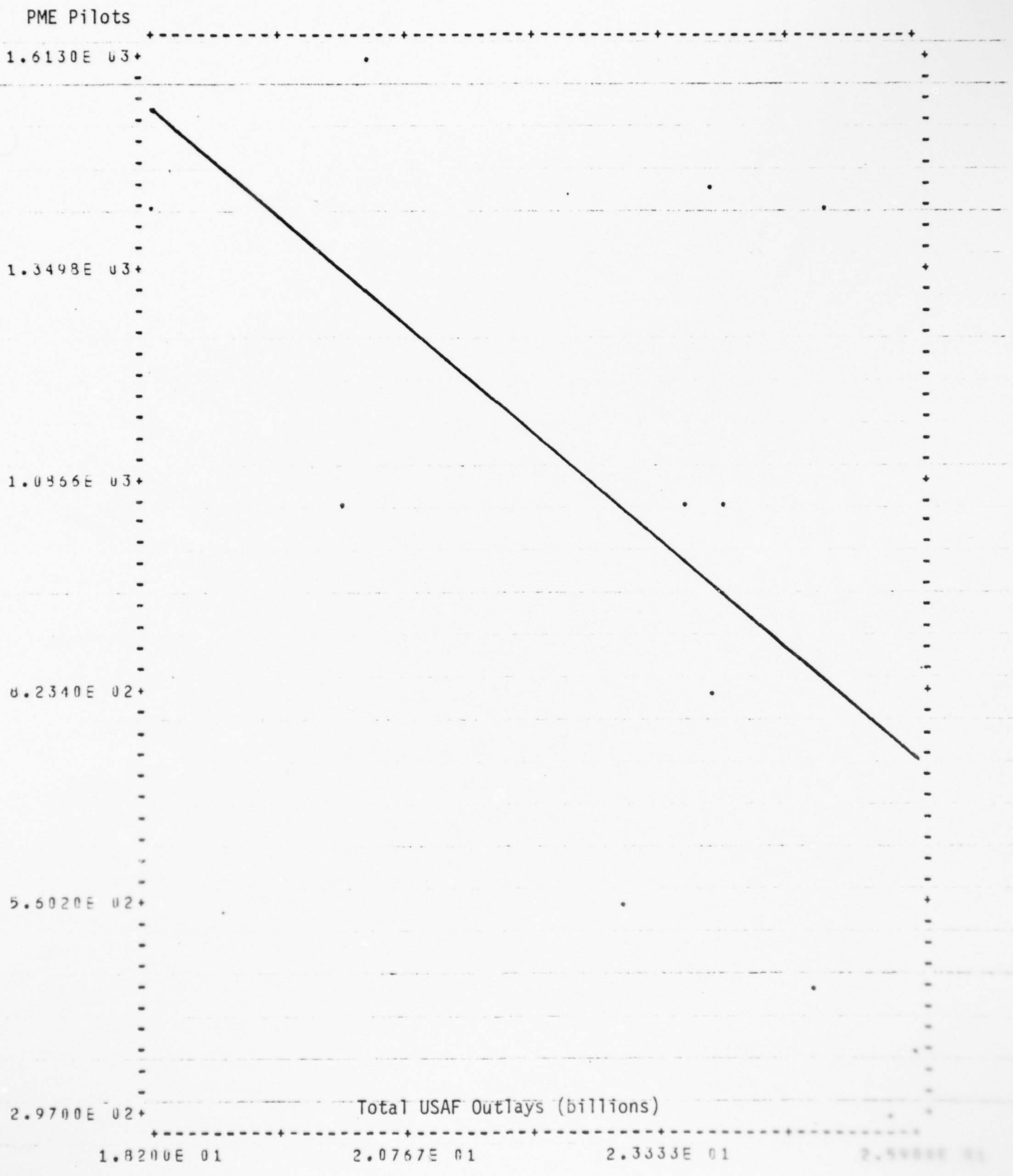

Figure 14. PME Pilot Graph

AD-A036 380 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 5/9
POTENTIAL DISTRIBUTION OF THE RATED OFFICER FORCE AND THEIR IMP--ETC(U)
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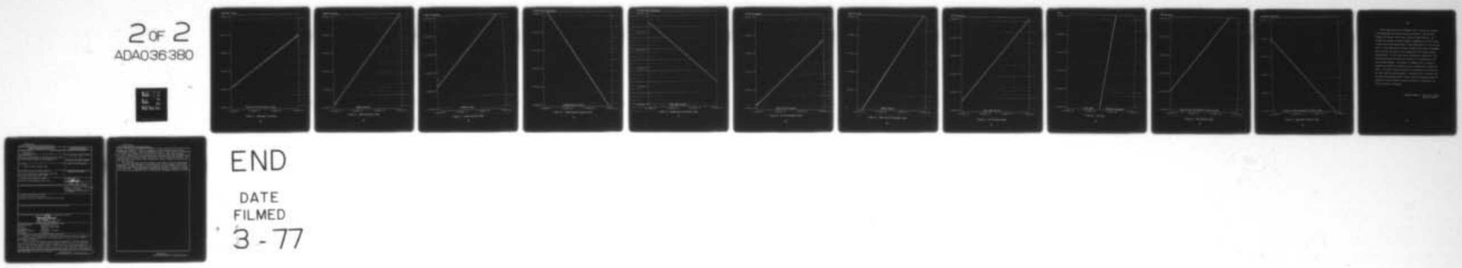

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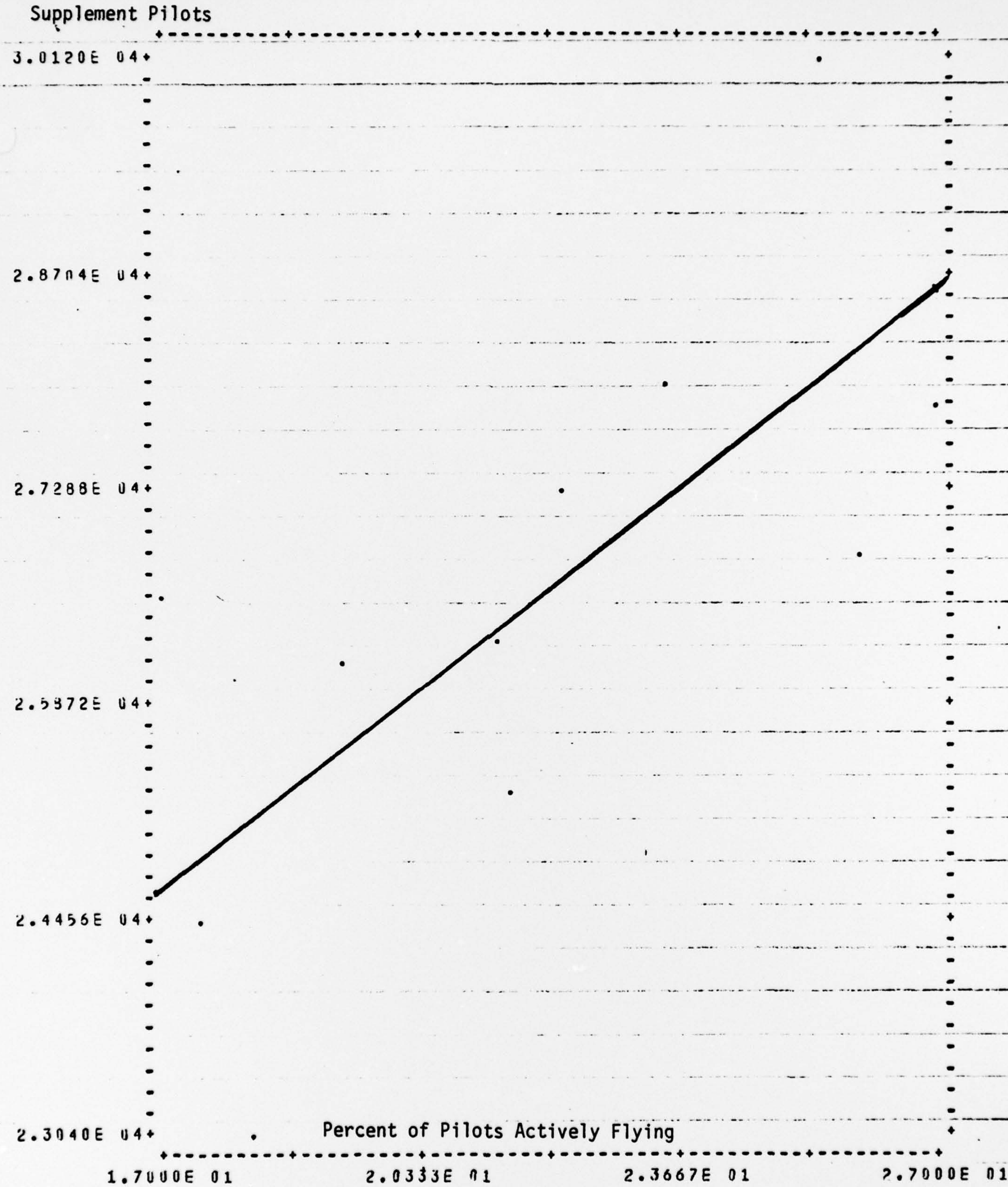

Figure 15. Supplement Pilot Graph

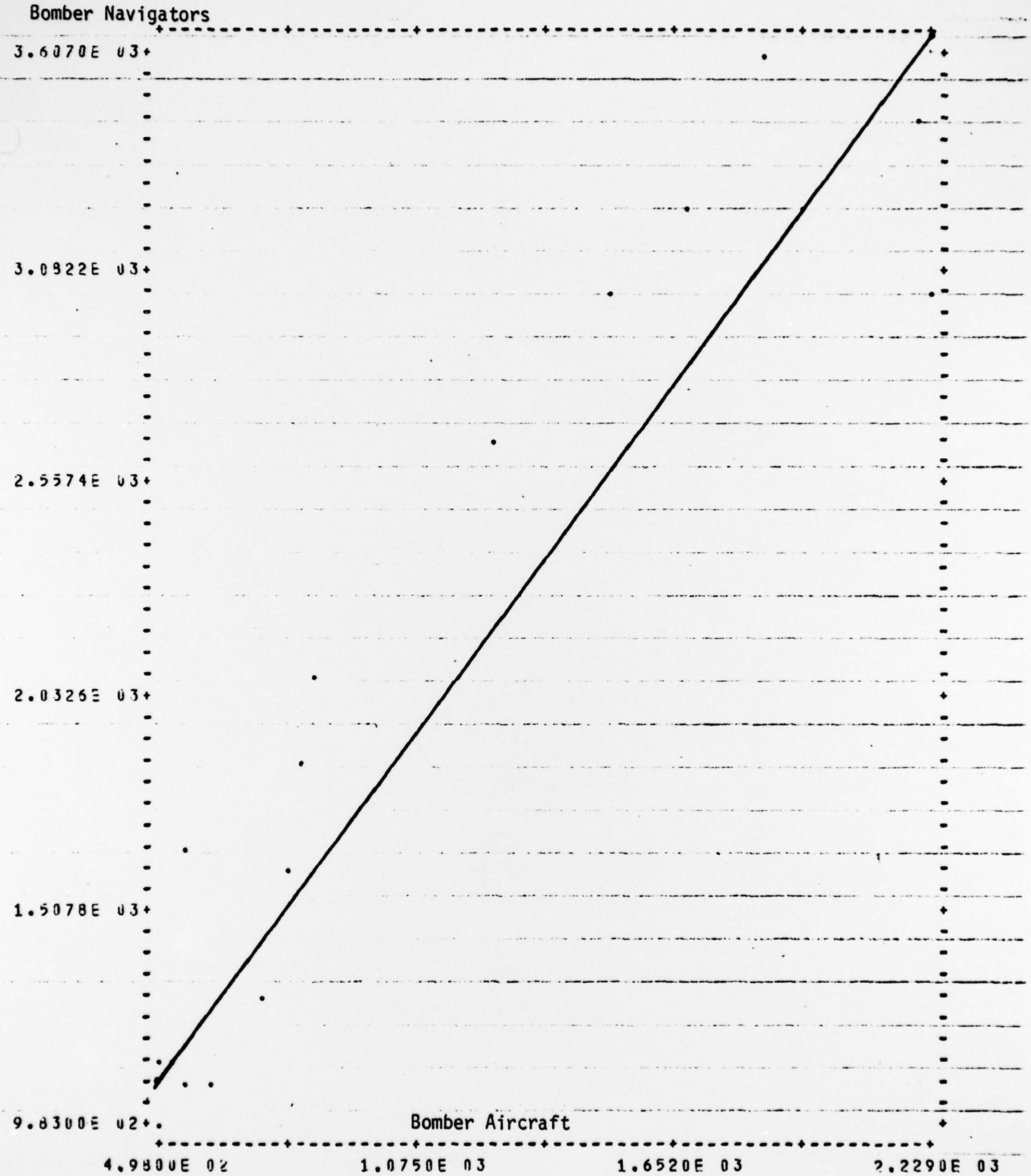

Figure 16. Bomber Navigator Graph

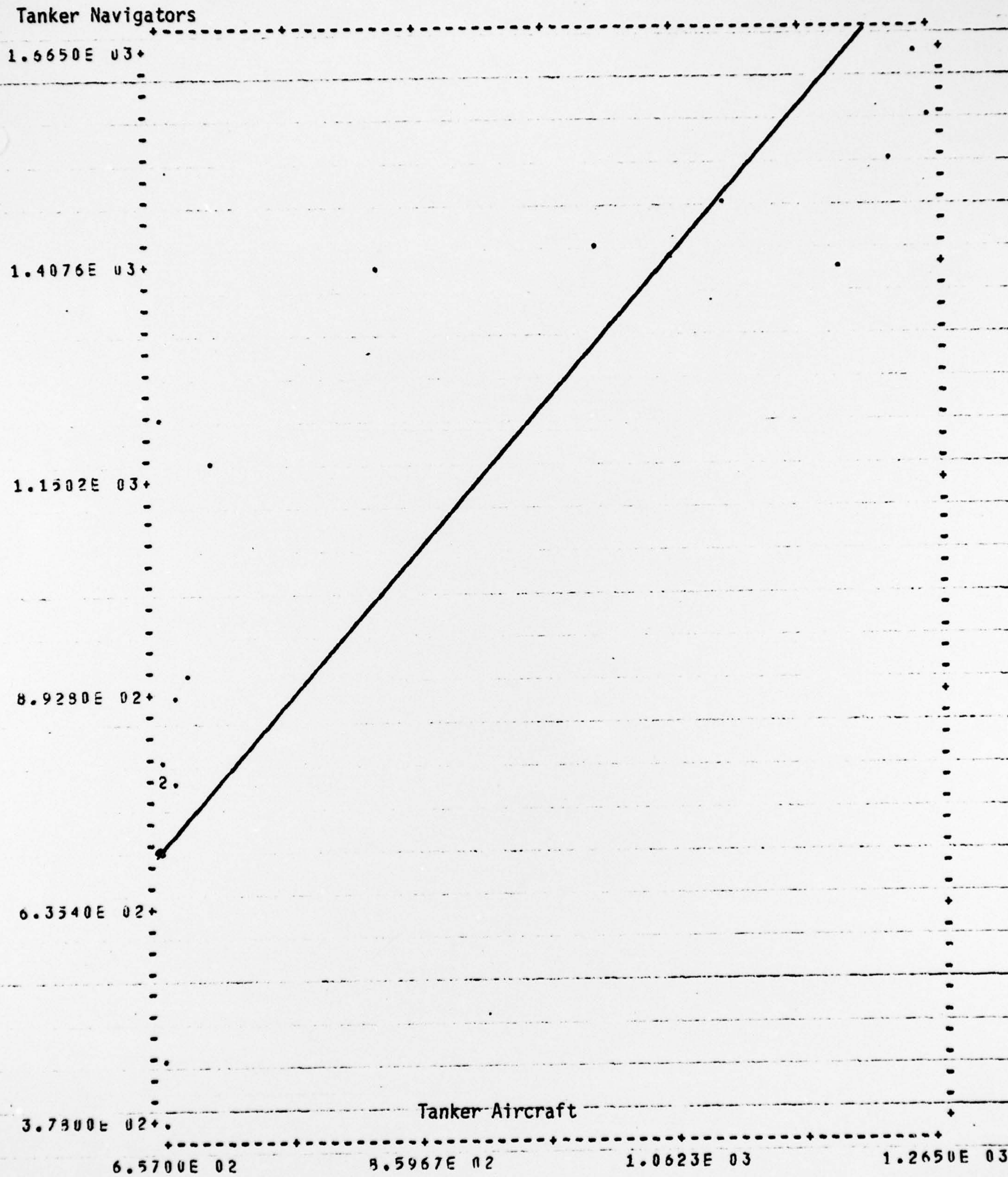

Figure 17. Tanker Navigator Graph

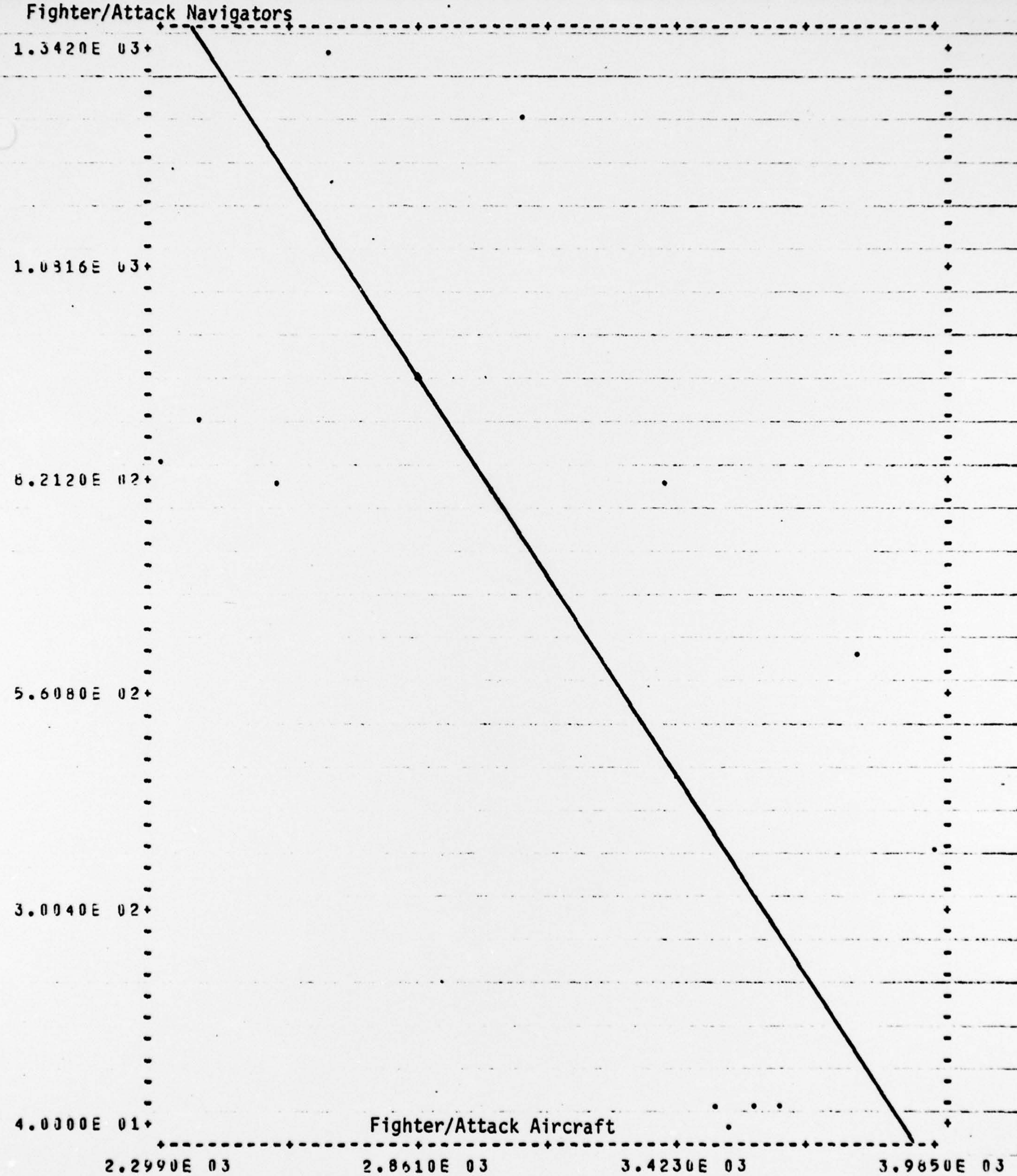

Figure 18. Fighter/Attack Navigator Graph

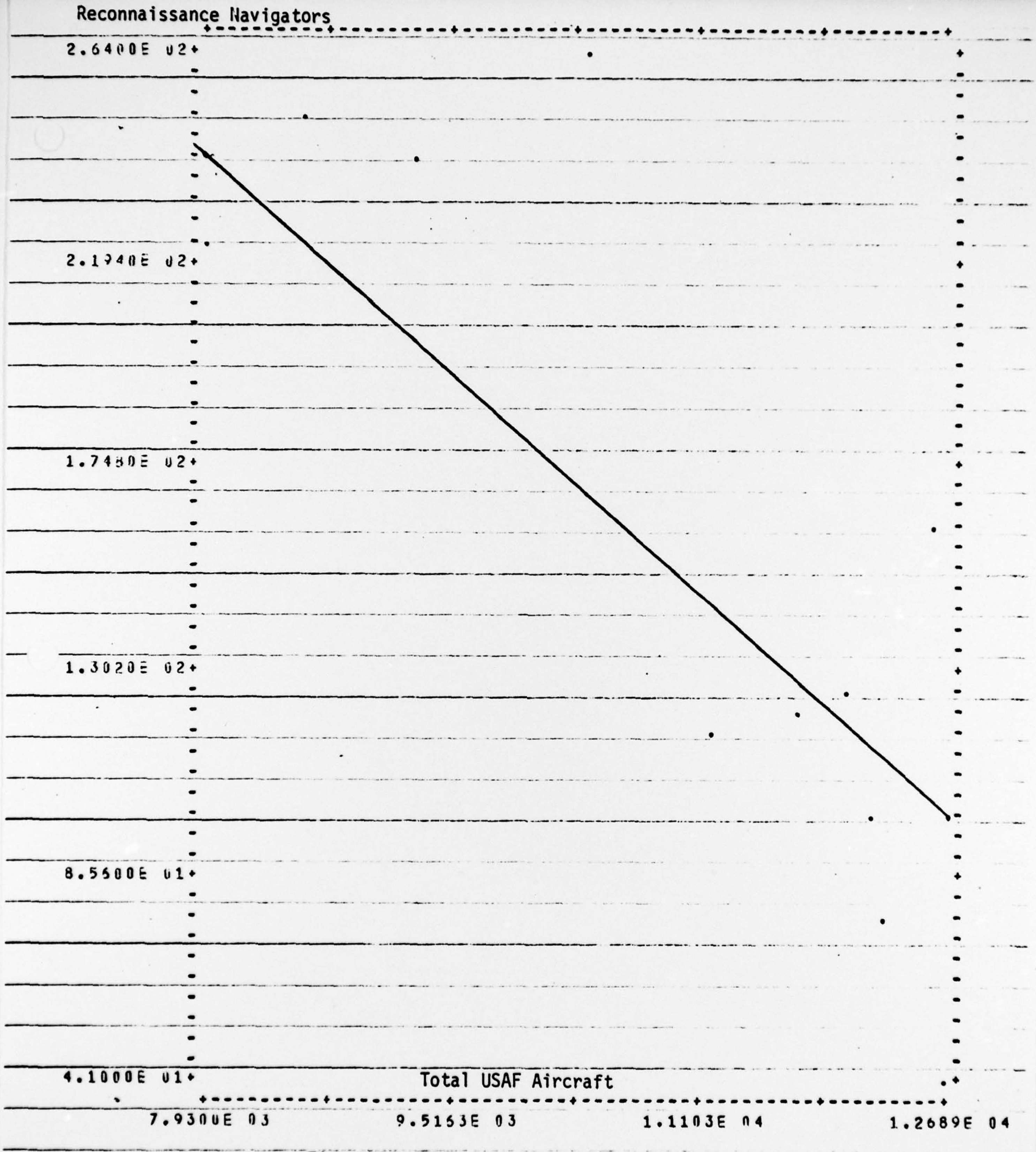

Figure 19. Reconnaissance Navigator Graph

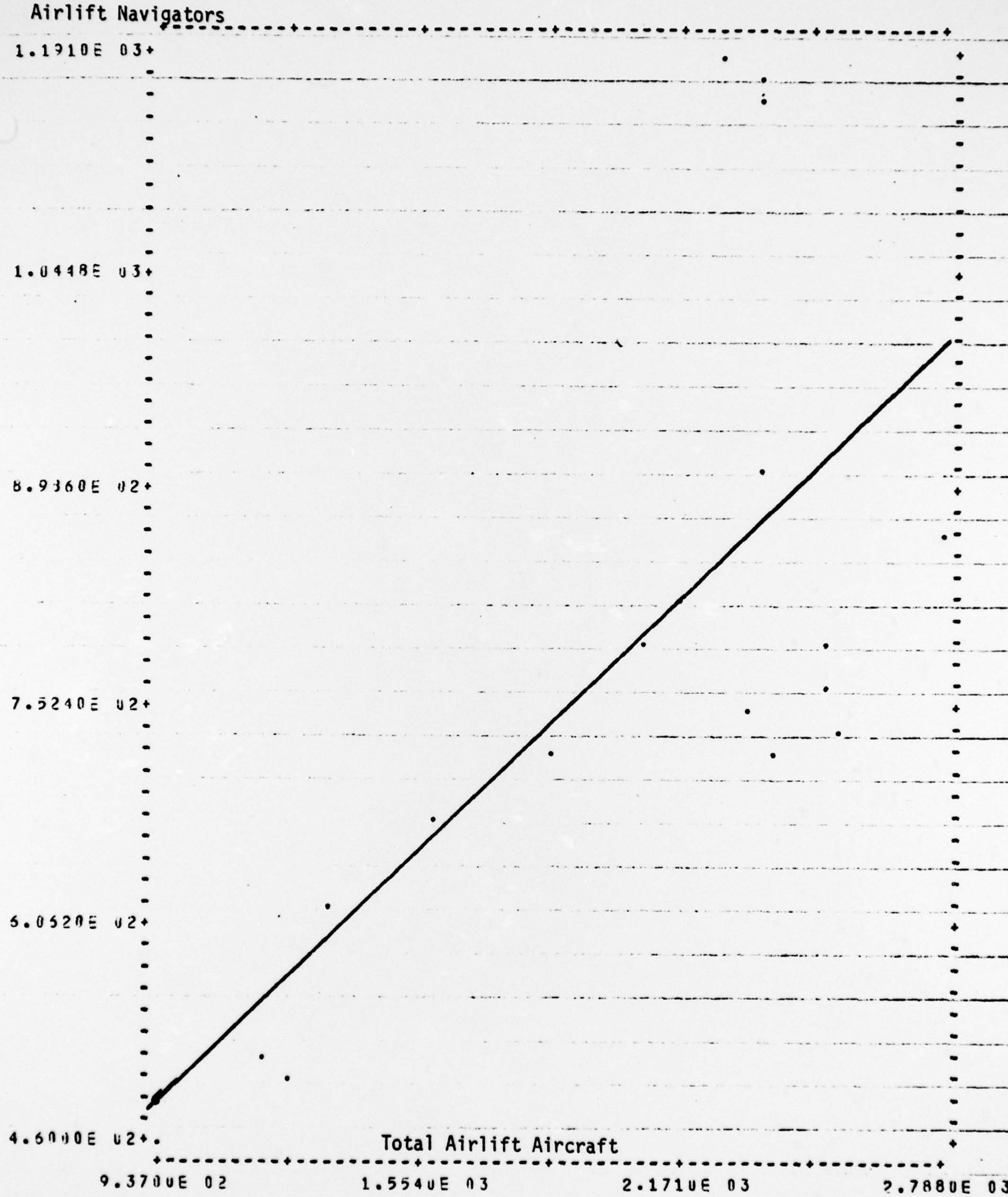

Figure 20. Airlift Navigator Graph

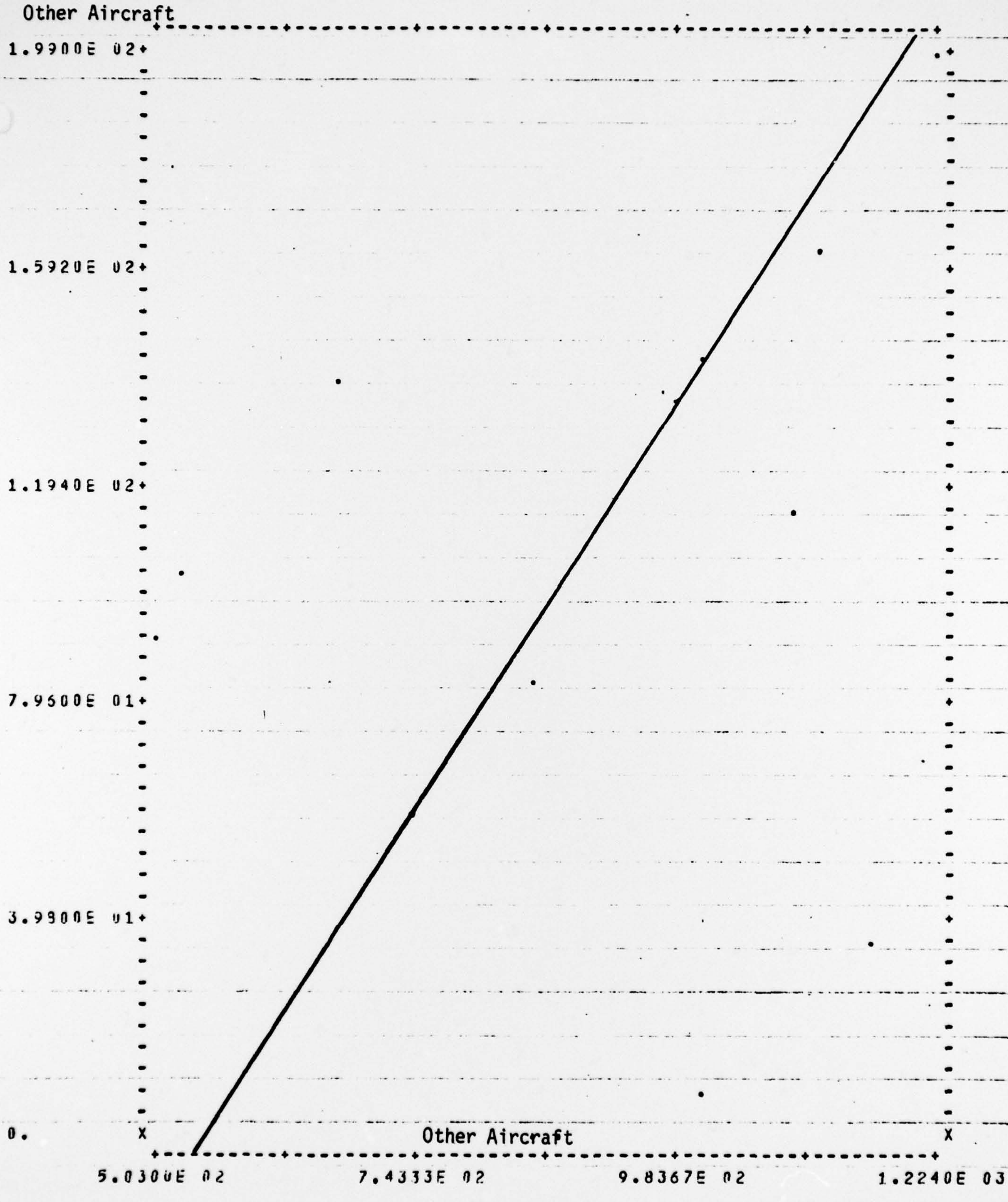

Figure 21. Other Aircraft Navigator Graph

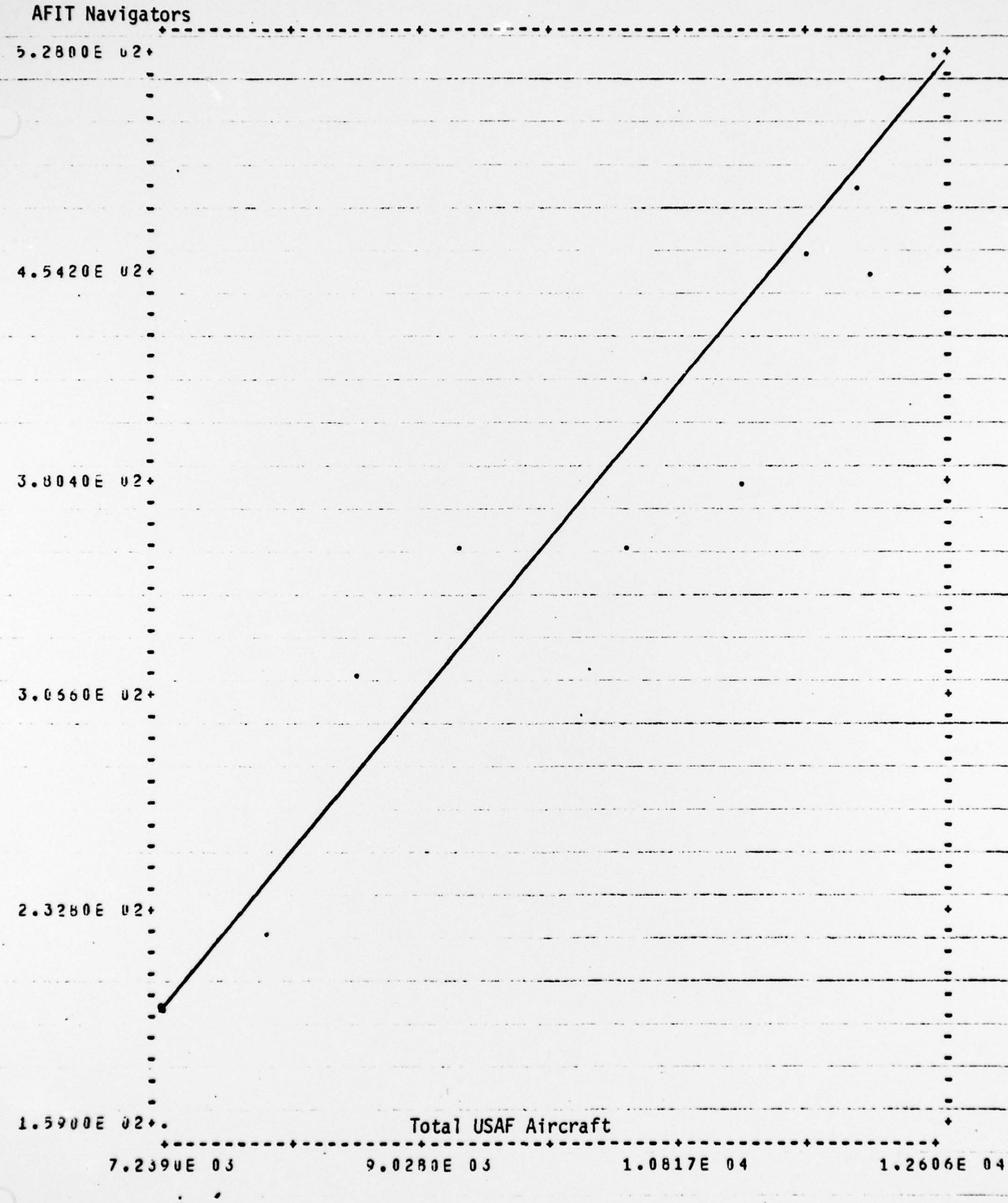

Figure 22. AFIT Navigator Graph

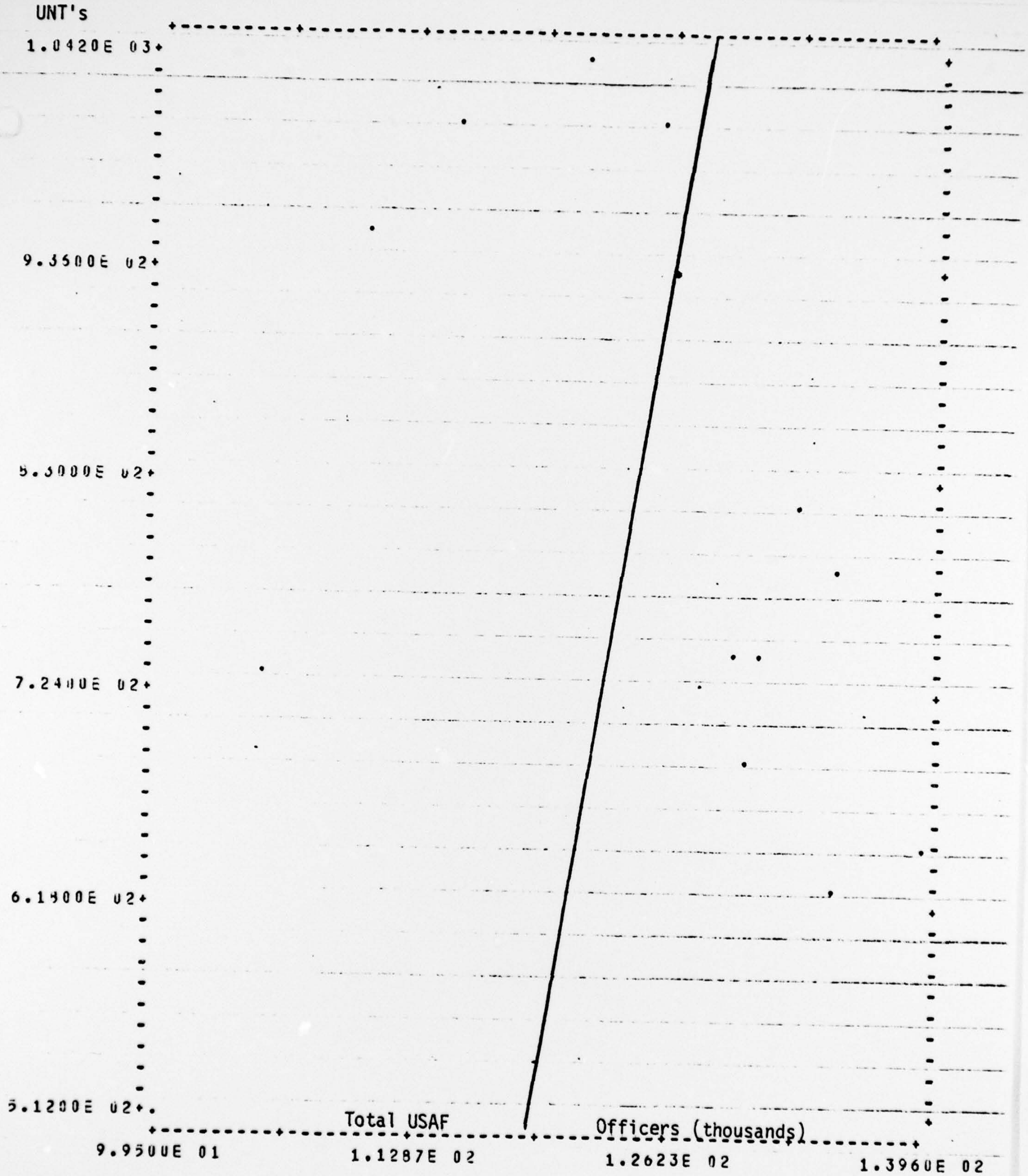

Figure 23. UNT Graph

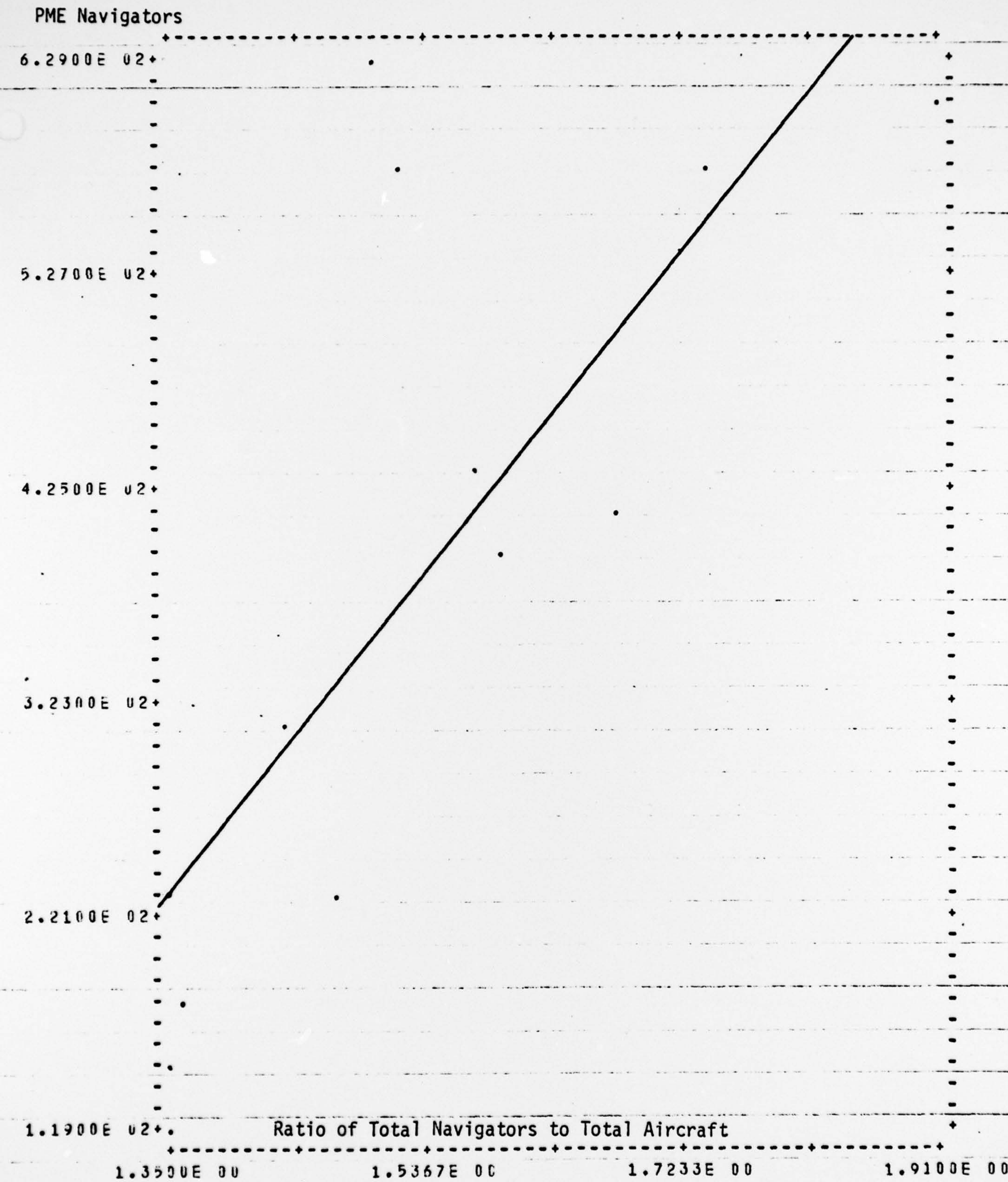

Figure 24. PME Navigator Graph

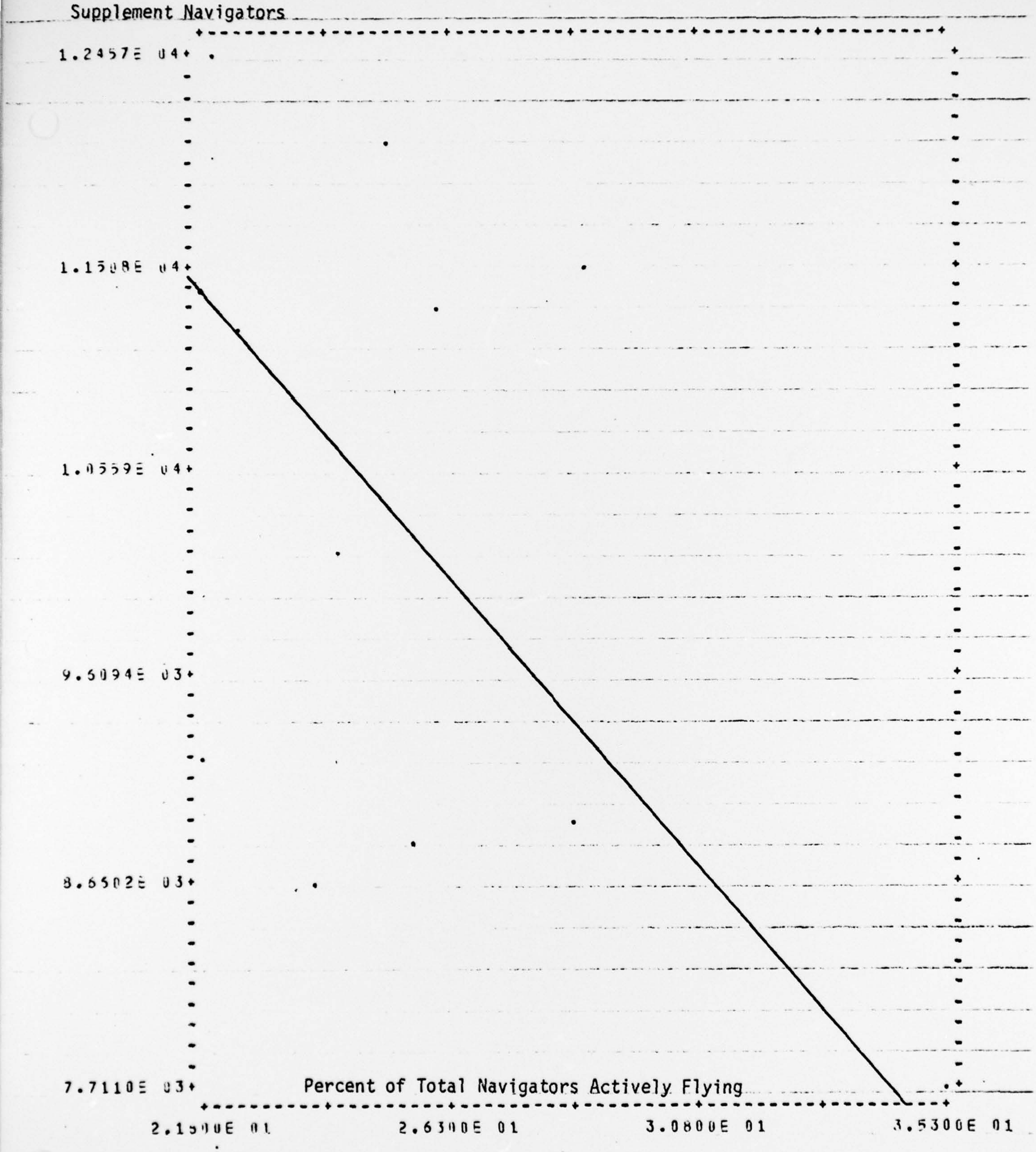

Figure 25. Supplement Navigator Graph

VITA

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 GOR/SM/76D-1	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 POTENTIAL DISTRIBUTION OF THE RATED OFFICER FORCE AND THEIR IMPLICATIONS IN FUTURE CONFLICT.		5. TYPE OF REPORT & PERIOD COVERED 9 Master's thesis,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 John M. Berry, Major, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (AFIT-EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/EN, Wright-Patterson AFB, OHio		12. REPORT DATE 11 December 1976
		13. NUMBER OF PAGES 106 12 110p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Report & Appendix A: UNCLASSIFIED Appendix B: SECRET
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

For Basic Report and Appendix A

Approved for public release; distribution unlimited .

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES Approved for public release; IAW 190-17

Jerral F. Guess, Capt, USAF

Director of Information

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rated officers	Regression analysis
Pilots	Standard linear model
Navigators	Forecast
Manpower Planners	Prediction intervals
Stochastic	Aircraft

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Changes in the composition of the USAF rated officer force are viewed as a stochastic process influenced by the decisions of individual service members and manpower planners.

Both pilots and navigators are considered separately. Data are developed based on the product of crews formed by weapon system and pilots or navigators per crew for the same weapon system. Rated officers are then aggregated into broad categories for further analysis. Multiple linear regression conforming to the Standard Linear Model is used to develop the explicit forms of relationships

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between the numbers of pilots or navigators in the categories and relevant independent variables. The basic hypothesis tested is that pilots or navigators in a particular category are a function of aircraft in that same cateogry. Using this hypothesis as an underlying guide, some 20 models are developed which are then used to forecast future distributions of the rated officer force. The implications of the analysis are discussed in light of potential wartime needs for rated officers.

The study concludes that the Standard Linear Model is apt for the problem addressed and large variance is a characteristic of the manpower system under examination, and ~~that~~ forecasting with reasonable accuracy in this way is virtually impossible. Other significant observations include a tendency to overman pilot force and an apparent delay in planning for navigators relative to pilots.

(There also seems to be)